

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problem Mailbox.**

L Number	Hits	Search Text	DB	Time stamp
-	2096	ion adj implanter	USPAT; JPO; DERWENT	2004/02/20 09:41
-	4769	rubber adj plate	USPAT; JPO; DERWENT	2004/02/19 17:01
-	2	(ion adj implanter) and (rubber adj plate)	USPAT; JPO; DERWENT	2004/02/19 17:05
-	422210	template or mask	USPAT; JPO; DERWENT	2004/02/19 17:05
-	125	(rubber adj plate) and (template or mask)	USPAT; JPO; DERWENT	2004/02/19 17:05
-	92	((rubber adj plate) and (template or mask)) and (trim\$4 or etch\$3 or remov\$3)	USPAT; JPO; DERWENT	2004/02/19 17:10
-	1	(ion adj implanter) and (((rubber adj plate) and (template or mask)) and (trim\$4 or etch\$3 or remov\$3))	USPAT; JPO; DERWENT	2004/02/19 17:06
-	467	(ion adj implanter) and (template or mask)	USPAT; JPO; DERWENT	2004/02/19 17:06
-	9	((ion adj implanter) and (template or mask)) and rubber	USPAT; JPO; DERWENT	2004/02/19 17:06
-	5	(ion adj implanter) with rubber	USPAT; JPO; DERWENT	2004/02/19 17:09
-	686	template same rubber	USPAT; JPO; DERWENT	2004/02/19 17:10
-	434	(template same rubber) and (trim\$4 or etch\$3 or remov\$3)	USPAT; JPO; DERWENT	2004/02/19 17:10
-	159	(template same rubber) same (trim\$4 or etch\$3 or remov\$3)	USPAT; JPO; DERWENT	2004/02/19 17:10
-	64	(template) same ((trim\$4 or etch\$3 or remov\$3) with rubber)	USPAT; JPO; DERWENT	2004/02/19 17:18
-	25275	((trim\$4 or etch\$3 or remov\$3) with rubber)	USPAT; JPO; DERWENT	2004/02/19 17:18
-	38	((trim\$4 or etch\$3 or remov\$3) with rubber) with template	USPAT; JPO; DERWENT	2004/02/19 17:18
-	231	83/565.ccls.	USPAT; JPO; DERWENT	2004/02/20 09:41
-	462	219/121.71.ccls.	USPAT; JPO; DERWENT	2004/02/20 09:42
-	693	83/565.ccls. or 219/121.71.ccls.	USPAT; JPO; DERWENT	2004/02/20 09:42
-	61	(83/565.ccls. or 219/121.71.ccls.) and templat\$2	USPAT; JPO; DERWENT	2004/02/20 09:47
-	11	((83/565.ccls. or 219/121.71.ccls.) and templat\$2) and laser	USPAT; JPO; DERWENT	2004/02/20 09:59
-	6	("5358986"   "5744776"   "5776566"   "5882572"   "5883356"   "5961143").PN.	USPAT	2004/02/20 09:49
-	2	("3931491"   "4362077").PN.	USPAT	2004/02/20 09:52
-	14	4458133.URPN.	USPAT	2004/02/20 09:52

-	7	("D141882"   "0647339"   "2478071"   "2552215"   "4382590"   "4458133"   "5673490").PN.	USPAT	2004/02/20 09:54
-	15	D141882.URPN.	USPAT	2004/02/20 09:55
-	6	3617683.URPN.	USPAT	2004/02/20 09:58
-	3	29/592.1,602.1.ccls. and templat\$2 and laser	USPAT; JPO; DERWENT	2004/02/20 09:59
-	16	29/592.1,602.1.ccls. and templat\$2	USPAT; JPO; DERWENT	2004/02/20 10:04
-	607	templat\$2 with laser	USPAT; JPO; DERWENT	2004/02/20 10:05
-	1	templat\$2 with laser with rubber	USPAT; JPO; DERWENT	2004/02/20 10:05
-	2096	ion adj implanter\$1	USPAT; JPO; DERWENT	2004/02/20 10:05
-	0	(templat\$2 with laser) and (ion adj implanter\$1)	USPAT; JPO; DERWENT	2004/02/20 10:06
-	2	(ion adj implanter\$1) and (rubber adj plate)	USPAT; JPO; DERWENT	2004/02/20 10:06
-	52	(ion adj implanter\$1) and (rubber)	USPAT; JPO; DERWENT	2004/02/20 10:06



## Welcome to IEEE Xplore®

- Home
- What Can I Access?
- Log-out

## Tables of Contents

- Journals & Magazines
- Conference Proceedings
- Standards

## Search

- By Author
- Basic
- Advanced

## Member Services

- Join IEEE
- Establish IEEE Web Account
- Access the IEEE Member Digital Library

Your search matched **1 of 1006282** documents.  
A maximum of **500** results are displayed, **15** to a page, sorted by **Relevance Descending** order.

**Refine This Search:**

You may refine your search by editing the current search expression or enter a new one in the text box.

 Check to search within this result set**Results Key:**

**JNL** = Journal or Magazine **CNF** = Conference **STD** = Standard

**1 Formation of shallow P-type layers by implantation of molecular diborane ions**

*Yokota, K.; Nishimura, H.; Terada, K.; Nakamura, K.; Sakai, S.; Tanjou, M.; Takano, H.; Kumagai, M.;*  
Ion Implantation Technology Proceedings, 1998 International Conference on , Volume: 1 , 22-26 June 1998  
Pages:91 - 94 vol.1

[\[Abstract\]](#) [\[PDF Full-Text \(372 KB\)\]](#) **IEEE CNF**

## United States Patent [19]

Macken

[11] Patent Number: 4,458,133

[45] Date of Patent: Jul. 3, 1984

[54] METHOD AND APPARATUS FOR LASER ENGRAVING OF SMOKE-SENSITIVE MATERIALS

[76] Inventor: John A. Macken, P.O. Box 696, Santa Rosa, Calif. 95402

[21] Appl. No.: 371,536

[22] Filed: Apr. 26, 1982

[51] Int. Cl. 3 B23K 27/00

[52] U.S. Cl. 219/121 LG; 83/565; 83/925 CC; 219/121 LN

[58] Field of Search 219/121 LG, 121 LN; 83/925 CC, 451, 29, 565

[56] References Cited

U.S. PATENT DOCUMENTS

3,931,491 1/1976 Stumpf 219/121 LV X  
4,362,077 12/1982 Gerber 269/8

## FOREIGN PATENT DOCUMENTS

447072 9/1976 U.S.S.R. 83/925 CC

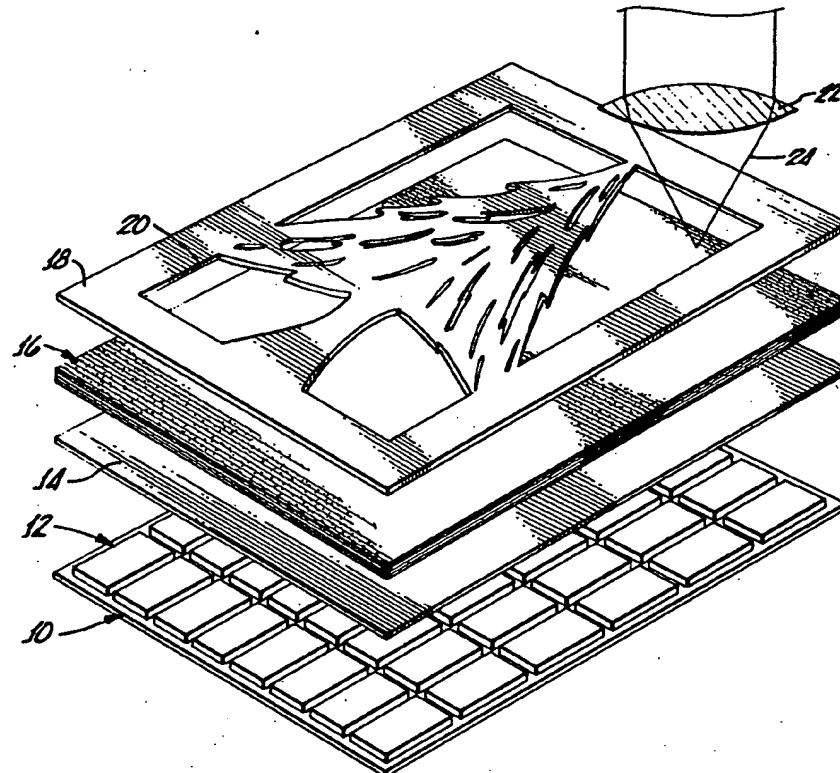
Primary Examiner—C. L. Albritton

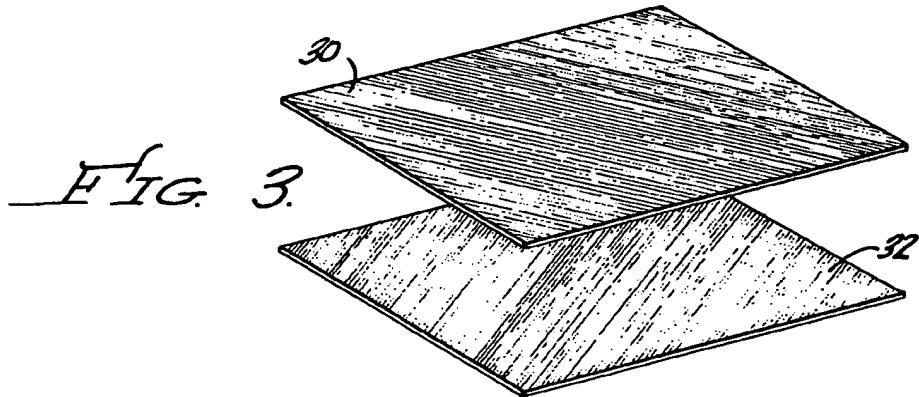
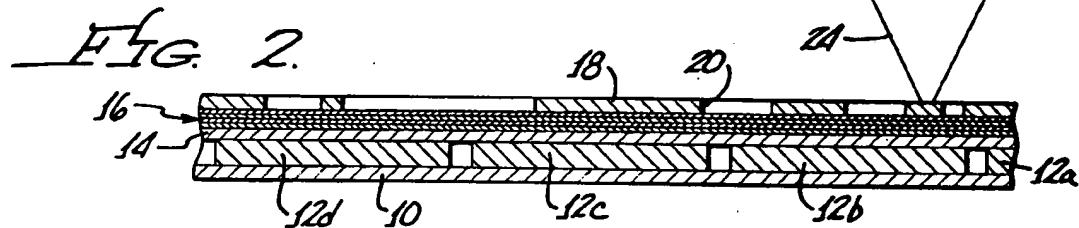
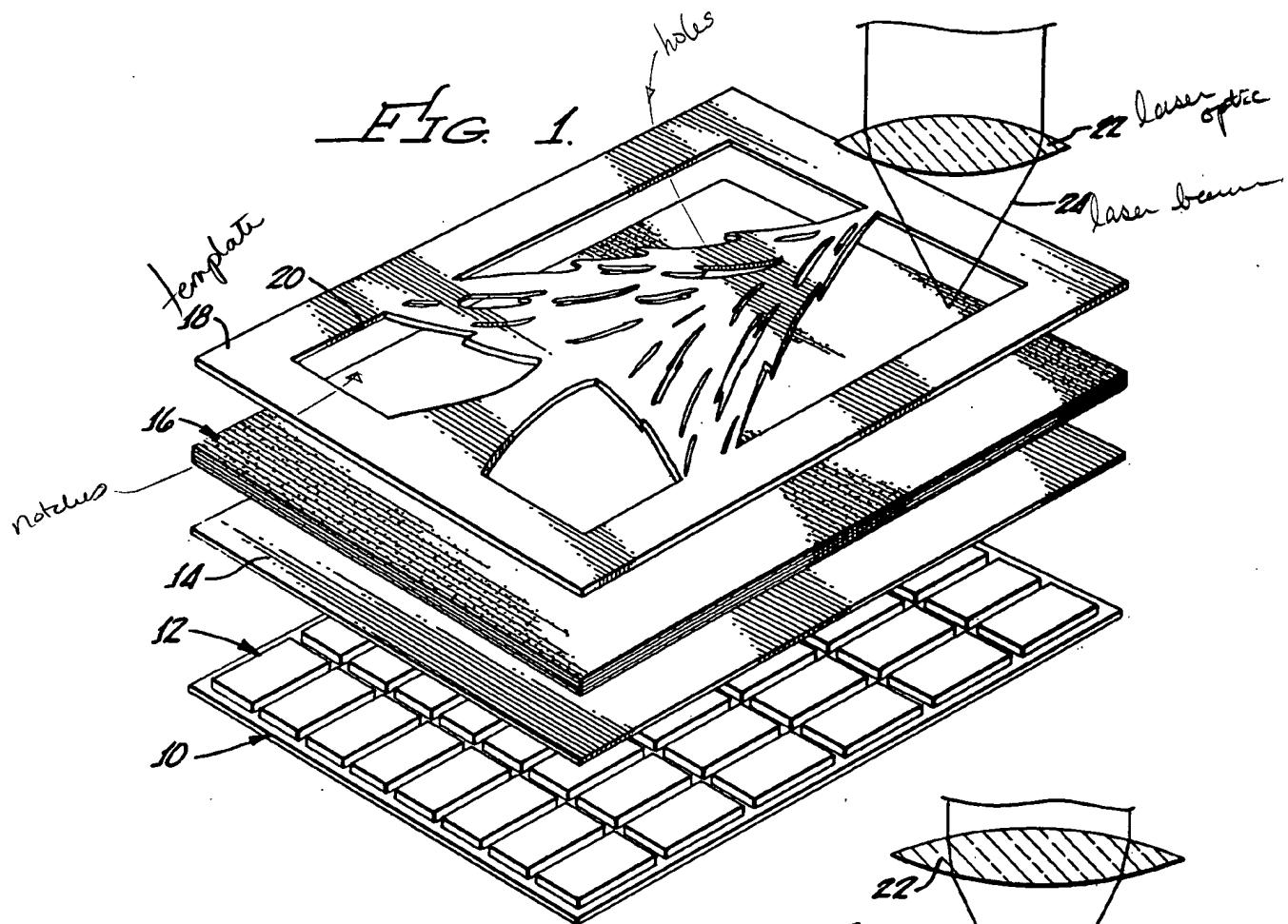
Attorney, Agent, or Firm—Edward E. Roberts

[57] ABSTRACT

A laser apparatus for use in laser cutting of a plurality of sheets of smoke-sensitive, heat-sensitive material in aligned stacked relation, the apparatus including a base member assembly for producing a magnetic field and for supporting the stack with a template formed of a generally rigid, magnetic material, the pull of the magnetic field on the template urging adjacent sheets into intimate surface contact to substantially eliminate voids therebetween during the cutting process. The template is preferably plated or coated with a reflective substance such as chromium, and the magnetic field may be created by an array of permanent magnets on a magnetic sheet.

15 Claims, 3 Drawing Figures





**METHOD AND APPARATUS FOR LASER  
ENGRAVING OF SMOKE-SENSITIVE  
MATERIALS**

**BACKGROUND OF THE INVENTION**

The background of the invention will be discussed in two parts:

1. Field of the Invention

This invention relates to laser apparatus and methods, and more particularly to a method and apparatus for engraving smoke-sensitive materials, such as paper, cloth and the like.

2. Description of the Prior Art

Laser engraving or cutting of items such as wood is well known to those skilled in the art. When wood items are engraved, normally a template made of brass is placed over the item, the template having openings therein in the form of the image or pattern to be engraved on the surface of the wood. The pattern is formed by chemical etching to remove the brass in the area desired. The template is provided with a peripheral frame which fits snugly about the wood item with the template in abutting relation with the surface to be etched or engraved by the laser beam. The laser beam, properly focused, is then scanned over the combination of the template and wood in some overlapping pattern so that there is relatively uniform coverage of the open areas in the brass template.

In such apparatus, it is usual to use a carbon dioxide laser having a power output in excess of 100 watts, with the beam being focused to a spot size intense enough to vaporize the wood to a given depth. Usually, power densities in excess of 30,000 watts per square centimeter are reached at or near the focus of the laser beam so that the wood can be cleanly vaporized. When vaporization occurs, the wood vapors escape from the part at high velocity. However, there is still condensation of these vaporized wood by-products on the surface of the wood and on the template. Usually, air flow prevents condensation of these vaporized wood by-products from taking place on the focusing lens or optics of the laser apparatus. When wooden items are engraved, the condensed vaporized wood by-products, or condensed smoke, can be cleaned from the wood item and from the template after the engraving is complete.

However, the above-described process and apparatus is not readily usable with thin, flexible, smoke-sensitive materials, such as paper and cloth, particularly where the laser is used to cut through the thin material, and more especially so when multiple sheets of the material are stacked to cut through several sheets or layers simultaneously.

For example, if multiple sheets of paper are stacked, and placed below a standard brass template and scanned with a laser beam several undesirable phenomena occur due to the smoke-sensitive and thermal-sensitive nature of the work piece. During the cutting process, the vaporized paper residue condenses on both sides of the paper along the cut edge, this deposit occurring on every sheet in the stack. This deposit has a brown tarnishing appearance and is somewhat sticky. In addition, this sticky residue deposits itself on the undersurface of the template, causing adherence of the top sheet of paper to the template adjacent the cut edge. It is uneconomical to remove the deposit from the sheets of paper, thus rendering this process unsuitable for cutting paper in stacked layers. In addition, with stacked sheets of

paper, the paper near the top of the stack goes through dimensional changes as the lower sheets are cut due to the intense heat involved. Due to these thermal effects, and the dimensional changes, there is movement of the upper sheets of paper, which causes the openings formed therein to increase in size to the extent that many fine lines, which are intended to be left as strips of paper, are in fact, eliminated.

It is an object of the present invention to provide a new and improved apparatus and method for laser cutting of paper, or similar thin smoke-sensitive material.

It is another object of the present invention to provide a new and improved method and apparatus for laser cutting of a stack of sheets of material, such as paper or the like.

It is still another object of the present invention to provide a new and improved process and apparatus for laser cutting of cloth of different compositions.

**SUMMARY OF THE INVENTION**

The foregoing and other objects of the invention are accomplished by providing a template formed of a generally rigid magnetic material for placing over sheets of material to be cut with a base plate therebelow, in general alignment with the template. The base plate includes means for providing a magnetic field for attracting the template toward the base plate to apply pressure to the sheets of material stacked therebetween. In the preferred embodiment, the template is formed of steel with both sides thereof coated with chromium. The base plate is an assembly having a generally rigid, non-magnetic sheet, or plate, of brass, or the like, for abuttingly engaging the lower surface of the stack of material, with a sandwich layer of ceramic magnets therebelow, the magnets being positioned with alternating polarities on a base plate member of a suitable magnetic material, such as galvanized steel.

The selection of magnets and magnetic as well as non-magnetic materials, as well as the dimensions thereof, and selected for providing a generally uniform pressure over all areas of the template in contact with the upper surface of the first sheet of material.

For laser cutting of materials, such as cloth, adjacent layers are provided with intervening materials, or, the intervening layers may be the same material with a different thread orientation, depending on the result desired.

Other objects, features and advantages of the invention will become apparent from a reading of the specification, when taken in conjunction with the drawings, in which like reference numerals refer to like elements in the several views.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is an exploded perspective view of the apparatus according to the invention with the stack of material depicted in its operative position;

FIG. 2 is an end view of the apparatus and material of FIG. 1 showing the relation therebetween in the assembled state ready for engraving; and

FIG. 3 is a perspective view of two sheets of material in overlapping, angular grain orientation for use with the apparatus of FIGS. 1 and 2.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

As heretofore discussed, the use of a brass template for laser cutting or engraving of a stack of sheets of material having pliable, thermal-sensitive as well as smoke-sensitive characteristics is not economically feasible. The present invention contemplates the application of pressure to the stack in order to avoid dimensional changes during laser cutting, as well as to avoid residue deposits from the combustion by-products. This application of pressure, as will hereinafter be described, is by the use of magnetism; or electromagnetism, for creating a magnetic field which clamps the opposing surfaces of the stack into close relation under the force of the magnetic clamp or "vise".

The apparatus and method to be described has application with numerous types of sheet materials, of different thicknesses, and densities, with certain parameters being adjusted to accommodate the material used. For example, certain cloths, such as polyester thread woven cloths, have a grain structure, as well as fusible characteristics. Cloths made of natural fibers, such as cotton and silk, do not exhibit the tendency to "weld" or fuse together along the laser cut. Methods, taking into consideration these characteristics, will be discussed.

Referring now to the drawings, and more particularly to FIGS. 1 and 2, there is shown a base, or support plate 10 of a generally rectangular, planar configuration, having suitably mounted on the surface thereof, a matrix or array of magnets 12. A second base or support plate 14, configured, dimensionally, generally identical to the plate 10, overlies the matrix of magnets 12. The plate 14 serves to support a stack 16 of the sheets of material to be cut. Overlying the top sheet of material in the stack 16 is the template 18 having openings 20 formed therein, in the image or pattern desired for cutting in the stack 16.

A source of laser energy (not shown) is focused through a lens 22 to provide a focused laser beam 24 which scans the template 18 in any convenient manner, such as an overlapping raster scan to provide the desired cut in the stack 16. Scanning of the laser beam can be accomplished by movement of laser optics (22) or movement of the work (10,12,14,16,18,20) or both.

The discussion thus far has proceeded with reference to the mechanical layout of the assembly, without reference to details. The plate 10 has several requirements. Initially, it should be made of a magnetic material, and secondly, it must be sufficiently rigid for the intended purpose, or provided with a rigid backing. In the embodiment illustrated, the plate 10 is formed from a galvanized steel of 0.03 to 0.07 inches thick. The individual magnets 12a, 12b, 12c, etc. are made of ceramic magnet material with a residual inductance rating of 3.8 kilogauss, with dimensions of 1.7 inch square by 0.18 inch thick. The magnets 12a, 12b, etc. have the magnetic pole orientation in the 0.18 inch dimension, that is, the poles are perpendicular to the plane of the galvanized plate 10. Each magnet 12 is placed on the galvanized plate 10 with the polarity of adjacent magnets reversed. The array of magnets 12, positioned in an abutting relation to form a layer, produce a fringing magnetic field at a distance between 0.03 inch and 0.30 inch above the upper surface of the layer or array.

The second plate 14 in the embodiment described is a layer or sheet of a non-magnetic material, such as a sheet of brass having a thickness of 0.010 inch. This

plate is not absolutely essential, but serves to smooth out any irregularities caused by the upper surfaces of the array of magnets 12. Alternatively, the magnets 12 may be encapsulated, potted, or covered with a surface coating to provide a smooth upper surface on which the stack 16 of sheets of material is positioned. This coating, or brass plate 14, if used, additionally assists in protecting the paper or other material to be cut from any surface debris from the magnets 12, most commonly, a form of "soot" (with permanent ceramic magnets). While it is not necessary to have the plate 14 made of brass, the plate (or coating) is desirably formed of some nonmagnetic material or composition which will not attenuate the magnetic field, and of a thickness sufficiently small to still provide the desired magnetic force at the desired height above the surface consistent with the height of the stack 16 being engraved or cut.

To complete the assembly, the template 18 is formed of a suitable magnetic material of sufficient rigidity and thickness to exert the required pressure on the stack 16 without deformation. The principle of the present invention is to exert sufficient pressure on the stack 16, which must be substantial and generally uniform over the paper everywhere that the template 18 comes into contact. It is also necessary that the template 18 hold down tightly against the top sheet and conform, if necessary, to slight variations in the surface flatness of the stack 16 of paper or other material. Ordinary metal templates, such as brass, which are usually used with a frame, cannot exert the pressures required, even if the brass is previously coiled, or bent. For the purposes of the instant invention, the material from which the template 18 is made is 0.0125 inch thick steel, thus providing the necessary rigidity and magnetic properties. For increasing the life of the template 18, it is very desirable that at least the surface opposite the stack (upper) thereof be coated, or plated, with a material having reflectivity (to reflect the laser beam in the solid areas) and smoothness (to facilitate removal of the template from the paper after cutting, with a minimum of adhesion). For this purpose, at least one surface can be coated with either chromium, nickle, brass, tin, silver or copper. It has been found that without this coating, bare steel templates are destroyed after about two or three uses. With this coating, very long lifetimes are possible. For producing the template 18, conventional etching processes are employed. The steel sheet (with chromium coating) is coated with photo-resist layers, and etched in a ferric chloride solution to produce a desired pattern 20, which would ultimately be the image formed in the stack 16.

By way of example, the stack 16 of paper or other material includes 10 sheets of paper, each sheet having a typical thickness of 0.004 inch, the entire stack measuring 0.04 inch in height. Essentially, with the parts as assembled as shown in FIG. 2, the distance between the upper surface of the array of magnets 12 and the lower surface of the template 18 with the stack 16 therebetween will be approximately 0.05 inch. This distance is well within the desired parameters for the exemplary materials described for producing a fringing magnetic field at 0.03 inch to 0.30 inch above the surface of the magnets 12.

To vaporize through a single sheet of paper, it takes approximately 250 watt-seconds of energy per square inch at the surface. Therefore, in the instant example, the 10-sheet stack 16 of paper will be vaporized when approximately 2500 watt seconds of energy from the

laser beam 24 has been deposited per square inch over the surface in an overlapping scan. While details are not illustrated for providing the scan, conventional techniques may be employed such as a raster type scan, or a circular overlapping scan.

Utilizing the materials and configurations above-described, it has been found that substantial pressures can be exerted by the magnetic fields on the template 18, with the pressure being generally uniform over the surface of the stack 16 of paper. The magnetic pull on the template 18 exerted by the magnets 12 on the steel plate 10 approximates one-quarter pounds per square inch, which is sufficient not only to compress any voids between adjacent sheets of paper in the stack 16, but also to eliminate voids between the template 18 and the paper, and even to deform the template 18 to conform to variations in the thickness of individual sheets or layers of the material in the stack 16. In this regard, with the thickness selected for the template 18, any greater thickness would have made the template too rigid to allow it to bend slightly under the magnetic field. Therefore, it would not have eliminated voids as well, by being unable to easily conform to the surface of the paper. On the other hand, if the template 18 had been substantially thinner, the force exerted by the magnets 12 through the template 18 would be significantly reduced, thereby also producing a less desirable result.

The assembly thus described, with reference to a particular stack 16, of a particular material (i.e., paper) of a given number of sheets of a given thickness, has been found to prevent smoke residue from coating all the layers of paper, while eliminating voids between the layers of paper, to effectively prevent the paper from losing moisture content during the cutting process. This, in turn, greatly reduces any dimensional changes which one encounters in attempting to laser engrave a stack of paper using the brass template and frame.

While the description heretofore has described a particular set of materials, configurations, and parameters, it is to be understood that other modifications may be readily made to accommodate different materials or thicknesses. Although the magnetic field herein has been created by permanent magnets of ceramic material other means may be utilized to produce the magnetic field. For example, the magnetic field may be created as a potted layer of a composition having magnetic particles therein, provided the appropriate field is realized for the particular application. Electromagnetic devices may be employed to provide magnetic fields which can be selectively varied for differing applications, with the same hardware, to produce the same field at the template regardless of thickness of the stack 16. Similarly, the thickness of the template 18 is by way of example, for the paper stack 16 described. For other materials, or different thickness of the stack 16, it may be correspondingly desirable to deviate from this thickness to achieve the desired pressure and results. The various parameters may be readily determined by experimentation.

When using the apparatus hereinabove described for other materials, such as cloth, the desired end product, and the characteristics of the material to application of heat must be taken into consideration. For example, certain polyester materials are woven from a synthetic thread material which has the tendency to fuse at the point of application of heat. When two or more layers are stacked, there is a tendency for adjacent layers to fuse together, or weld, along the cut edge. In other

fabrics made of natural fiber, such as cotton or silk, this tendency does not manifest itself so readily. Plastic films likewise have a tendency to fuse at the cut edge. Polyester cloths, as well as natural fibers have a bias, or grain to the material, while plastic film does not.

Each of the characteristics, and the advantage or disadvantage of the characteristic is taken into consideration during the cutting or engraving process. If one wishes to cut synthetic materials, such as polyester cloth, there is some tendency for the laser beam to melt the cut thread ends so that the cloth does not tend to unravel. However, a single layer is considerably reduced in strength around the areas cut with the laser, since it is not too difficult to break the bond along the melted thread ends.

This problem can be greatly minimized if, by reference to FIG. 3, two layers of polyester cloth 30 and 32 are positioned one above the other with the thread directions (shown in broken lines) angularly oriented relative to each other, for example at an angle of 45 degrees relative to each other. Although not shown, three layers may be superimposed on each other with the "grain" or direction of thread orientation of adjacent layers oriented at 30 degrees relative to the adjacent layer. If desired, prior to cutting, the layers may be bonded together, or laminated.

When this laminated arrangement is laser engraved, using the apparatus herein described, the magnetically attracted template 18 applies pressure to the multiple layers of cloth 30 and 32, bringing them into intimate contact with each other, so that when the layers are cut by the laser beam 24, the cut edge of the two (or more) layers of cloth 30 and 32 fuse, or melt together, thus welding the layers of cloth together along the cut edge. This increases the strength of the cut edge of the cloth since, the melted edge is larger; the extra layer (or layers) of cloth increases the strength of the end-product; and the orientation of the threads of the two (or more) layers eliminates a major weakness in cloth, which is, that the strength of the cloth, along the cut edge, is reduced when forces are applied, to a single layer, in a direction at 45 degrees to the direction of the thread. For use in the garment industry, laser cutting may be conveniently employed, using the techniques herein described. The apparatus and method of multiple layers need not be used for the entire garment, but for certain portions requiring the structural strength obtainable, preferably with the extra layer (or layers) on the inside of the garment.

Plastic films exhibit the same "fusing" characteristics, and may readily be cut in abutting layers to form a weld along the cut edge. Alternatively, if it is desired to avoid the welding between adjacent layers, or between adjacent multiple-sheet layers, paper may be conveniently positioned in the intervening spaces to prevent welding of adjacent layers, as desired, within the stack. Thin sheets of paper, or other suitable non-fusible material placed between adjacent layers to prevent welding, may be used with either the polyester cloths, or with the plastic films previously discussed. After the stack is built up in the desired manner, the template 18 is positioned and the laser beam 24 energized and scanned. The applied pressure substantially eliminates the voids between adjacent materials, with the flexing of the template 18 due to the magnetic field conforming to the adjacent surface of the stack 16.

In applications using a stack of material other than paper, or having sheets of paper interleaved between

cloth or plastic or the like, the apparatus described may be readily employed, although variations in laser intensity may be required to accommodate the vaporization requirements for the different materials in the stack 16, such variations being within the skill in the art. While there has been shown and described a preferred embodiment, it is to be understood that various other modifications made be made without departing from the spirit and scope of the invention.

I claim:

1. In an apparatus for laser cutting of a stack of relatively thin sheets of material in aligned stacked relation, the combination comprising:

means for supporting the stack of sheets;  
means for providing a magnetic field; and  
template means formed of a magnetic material for placing on top of said stack, the magnetic forces of said magnetic field acting on said template means thereby urging adjacent sheets of material into intimate engagement with sufficient pressure for substantially eliminating penetration of laser beam generated vapors into spaces between said sheets of material.

2. The combination according to claim 1 wherein said template means has at least one surface comprised of a laser light reflective substance.

3. The combination according to claim 1 wherein said template means is formed from a sheet of generally rigid but slightly flexible material having at least a layer of material taken from the group consisting of chromium, nickel, copper, brass, silver and tin thereon at least the surface facing the laser beam.

4. The combination according to claim 3 wherein said template means is comprised of material taken from the group consisting of chromium, nickel, copper, brass, silver and tin.

5. The combination according to claim 1 wherein said means for supporting said stacks and said means for providing a magnetic field comprises a plate member formed of a magnetic material having an array of generally identical permanent magnets therein.

6. The combination according to claim 5 wherein said template is steel having at least one surface coated with a material taken from the group consisting of chromium, nickel, copper, brass, silver and tin.

7. The combination according to claim 5 wherein each of said magnets has the magnetic pole oriented perpendicularly to the plane of said plate member, with

adjacent magnets having the poles oriented in opposite directions.

8. The combination according to claim 1 wherein said support means has a generally planar surface and is positioned between the stack and said means for providing a magnetic field.

9. The combination according to claim 8 wherein said support means is a sheet of nonmagnetic material.

10. The combination according to claim 2 wherein said template means is formed of steel and said reflective substance is nickel.

11. In a method for laser cutting of sheets of material of a smoke-sensitive nature, such as paper, cloth or the like, the method comprising:

15 providing means for generating a magnetic field;  
providing a support assembly;

stacking sheets of said material on said support assembly in generally aligned relation;

20 placing a template formed of a magnetic material on said stack; and  
scanning the template with a laser beam having sufficient energy to vaporize the material exposed to the laser beam through the template, said magnetic field acting on said template to compress adjacent sheets of said material to prevent penetration of laser beam generated vapors into spaces between said sheets of material.

12. The combination according to claim 11 wherein the steps of providing a magnetic field and of providing 30 a support assembly includes providing a support plate formed of a magnetic material, and combining an array of permanent magnets with said support plate for creating the magnetic field.

13. The combination according to claim 11 wherein 35 the smoke-sensitive material is a polyester cloth material and said method further includes stacking of at least two adjacent sheets of such material with the thread orientations thereof in angular relation.

14. The combination according to claim 13 wherein the angular orientation is at an angle of substantially forty-five degrees.

15. The combination according to claim 11 wherein 45 the sheets of smoke-sensitive material have fusible characteristics, and said method further includes the step of positioning a non-fusible material between adjacent sheets of the smoke-sensitive material during the step of stacking thereby to prevent welding of said adjacent sheets.

\* \* \* \* \*



US006216354B1

(12) **United States Patent**  
**Carbone**

(10) Patent No.: US 6,216,354 B1  
(45) Date of Patent: Apr. 17, 2001

**(54) DEVICE FOR MAKING STRAIGHT AND CURVED SCORE LINES**

4,458,133 \* 7/1984 Macken ..... 83/565  
5,673,490 \* 10/1997 Hill ..... 33/566

(76) Inventor: **Martin R. Carbone, 1227 De la Vina  
St., Santa Barbara, CA (US) 93101**

FOREIGN PATENT DOCUMENTS

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

\* cited by examiner

*Primary Examiner*—Diego Gutierrez

*Primary Examiner—Diego Gutierrez  
Assistant Examiner—Yaritza Guadalupe*

(74) *Attorney, Agent, or Firm*—Christie, Parker & Hale,  
LLP

(21) Appl. No.: 09/145,013

## ABSTRACT

(22) Filed: Sep. 1, 1998

(51) Int. Cl. 7 ..... B43L 13/20

(52) U.S. Cl. .... 33/565; 33/563; 33/566;  
33/562; 33/27.01; 83/565

(58) **Field of Search** ..... 33/566, 565, 562,  
33/563, 27.01; 83/565

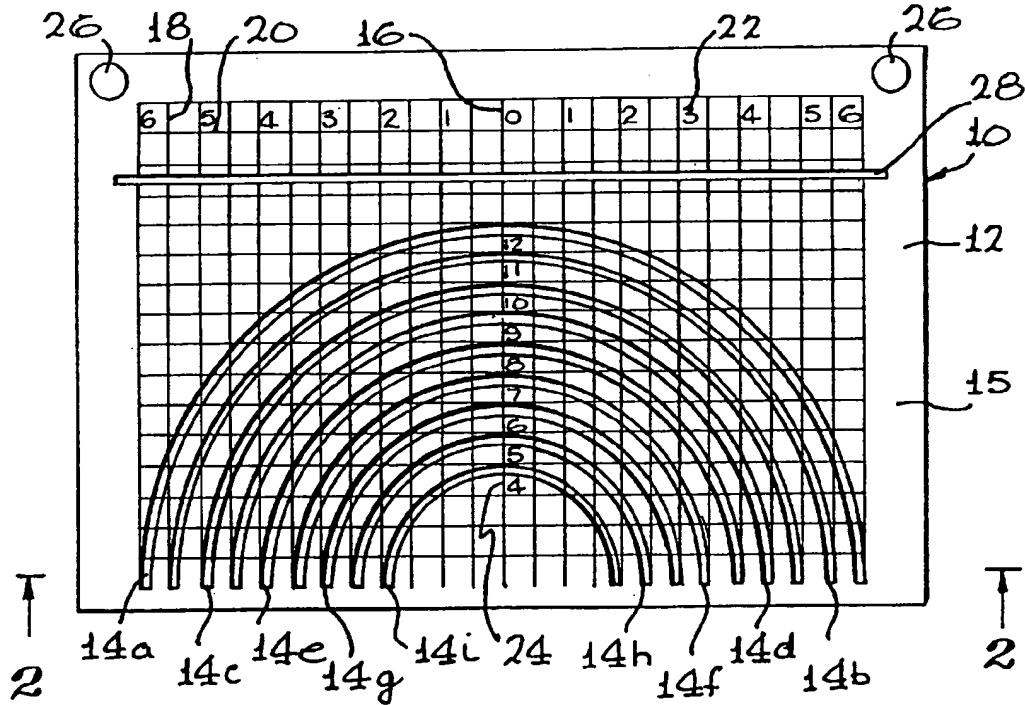
(56) **References Cited**

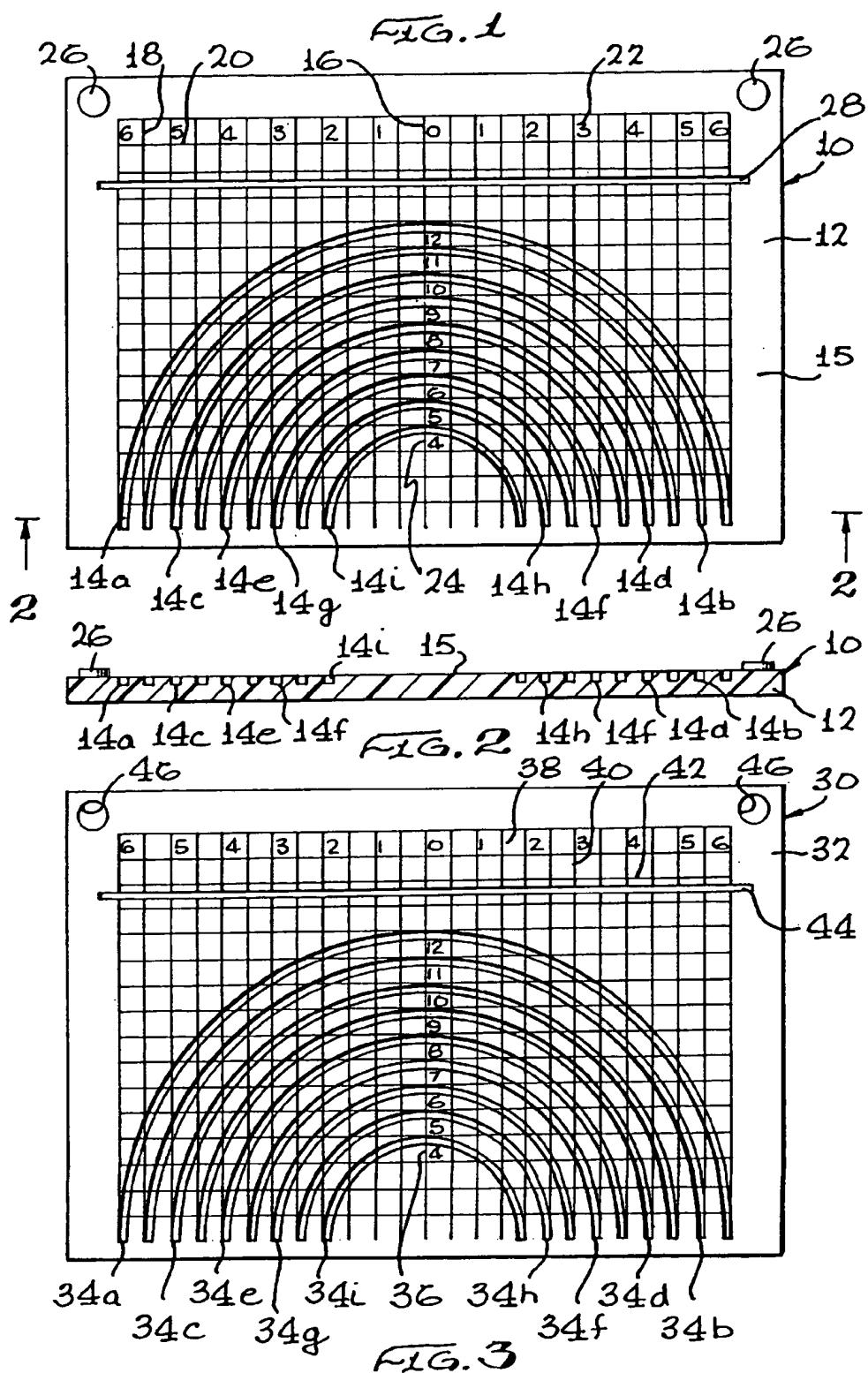
## U.S. PATENT DOCUMENTS

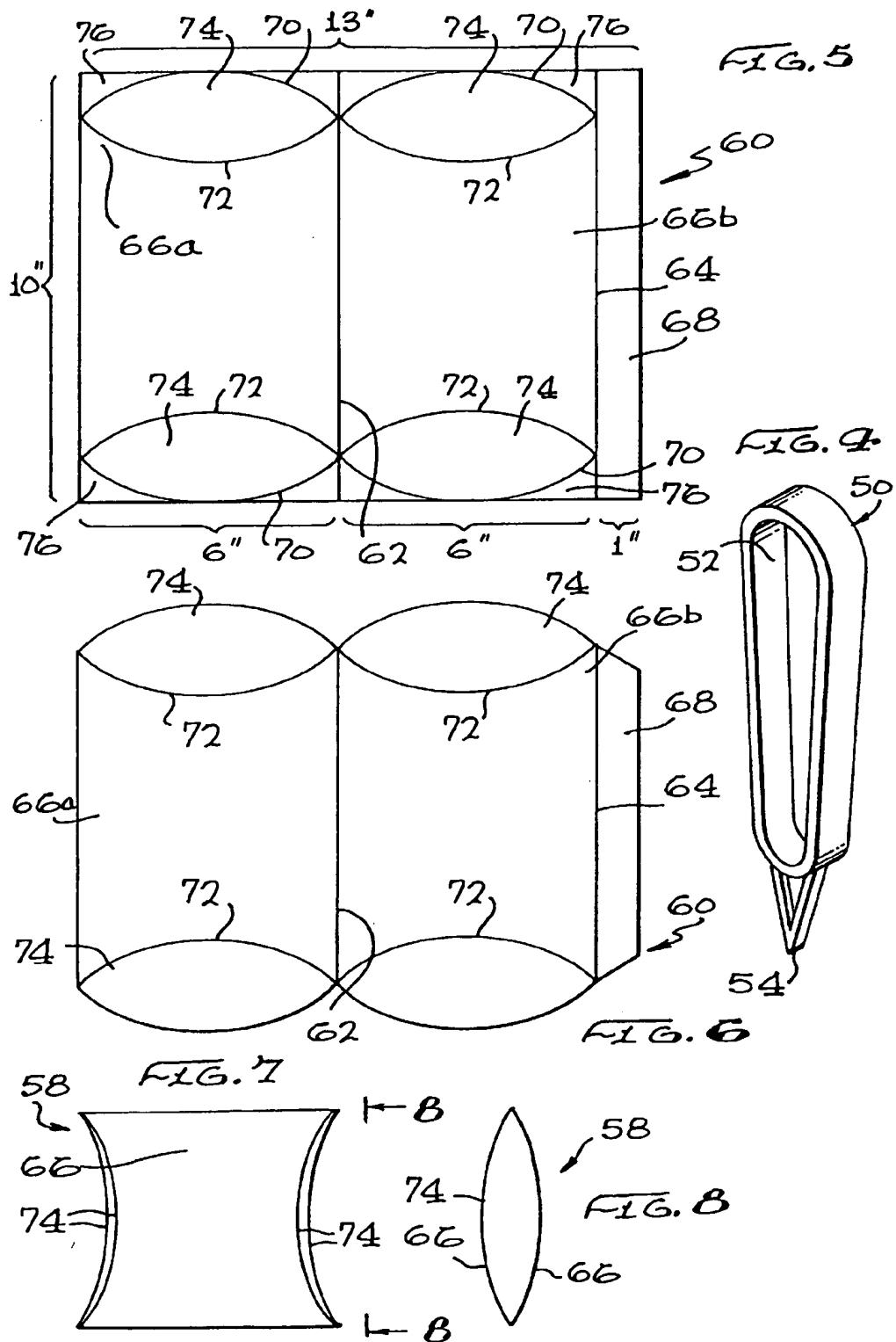
D. 141,882	• 7/1945	Matson .....	33/565
647,339	• 4/1900	Thompson .....	33/563
2,478,071	• 8/1949	Agrillo .....	33/565
2,552,215	• 5/1951	Reckdahl .....	33/565
4,382,590	• 5/1983	Pandya <i>et al.</i> .....	83/565

A device for forming straight and curved score lines in sheet material. The device has a scoring plate with a top surface with a number of spaced apart curved grooves formed on the top surface thereof. Each of the spaced apart scoring grooves has different radii of curvature. An optional overlay template portion has a number of spaced apart curved slots formed therein. The overlay template portion is adapted to overlay the scoring plate such that the spaced apart curved slots align with the grooves on the scoring plate when placed thereon. A scoring tool with a tip sized to fit into the grooves in the scoring plate and the slots in the optional template overlay portion is provided for scoring the sheet material.

**13 Claims, 2 Drawing Sheets**







## DEVICE FOR MAKING STRAIGHT AND CURVED SCORE LINES

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

This invention relates to the field of tools in the area of box making and scoring, and more particularly to a tool for making straight and curved score lines, such as for forming boxes, paper sculptures, toys, and artwork that include curved sides as part of their design.

#### 2. Description of the Prior Art

The inventor herein has obtained U.S. Pat. Nos. 5,484,373 and 5,707,327 and has a pending U.S. patent application No. 08/880,759 all directed to kits and methods of forming straight scoring lines for different type of boxes. The inventor has also filed a U.S. Provisional Patent Application No. 60/058,072 on Aug. 5, 1997 for an invention entitled "Curved Line Scoring Device". The device of this invention comprises a scoring plate with a plurality of grooves formed therein and a scoring tool for use in forcing the sheet material into a scoring groove to form a score line.

People are attracted to new and unique designs. In the area of box and container making, boxes with curved sides offer a refreshing break from the monotony of rectangular solid type boxes. Heretofore, other than the inventor's own invention "Curved Line Scoring Device" noted above, there has been no simple way for the do-it-yourselfer box maker, hobbyist, artist, and others who wished to create curved creases in card stock, cardboard, plastic, and other sheet material to do so. This can be very difficult to do consistently and repeatedly. Accordingly, there remains a need for a device for use in making curved score lines in sheet material.

### SUMMARY OF THE INVENTION

One object of the present invention is to provide a device for making score lines, particularly curved score lines, in sheet material such as card stock and plastic sheet material that is easy to use and which helps guide a user in forming perfect curved scoring lines in sheet material.

Another object of the invention is to provide a device for making curved and other shaped score lines in sheet material such as to form pocket boxes.

These and other objects of the invention are set forth below.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top view of a first embodiment of the scoring plate of the invention.

FIG. 2 is an end view of the scoring plate of FIG. 1 along view lines 2—2.

FIG. 3 is a top view of an optional scoring template overlay portion of the invention.

FIG. 4 is a top view of a scoring tool of the invention.

FIG. 5 is a plan view showing a sheet of cardstock scored to make a pillow box.

FIG. 6 is a plan view showing the scored cardstock of FIG. 5 cut as required.

FIG. 7 is a top view of a pillow box when folded.

FIG. 8 is an end view of the folded pillow box of FIG. 9 along lines 8—8.

FIG. 9 is a cross-sectional view of a sheet of material to be scored placed between the scoring plate and the template overlay portion.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2 a first embodiment of the scoring plate 10 of the invention is shown. Scoring plate 10 can comprise a planar base 12 with a plurality of semi-circular grooves 14 a-i formed therein in an upper surface 15 thereof. Grooves 14 a-i are preferably about 0.3175-0.476 mm ( $\frac{1}{8}$ " to  $\frac{3}{16}$ ") wide and about 0.3175-0.476 mm ( $\frac{1}{8}$ " to  $\frac{3}{16}$ ") deep. Dimensioned as such, grooves 14 a-i will function well for scoring paper cardstock having a thickness of about 0.025". For other thickness of material, the depth and width can be adjusted as required. Scoring plate 10 can conveniently be formed of plastic material with grooves 14 a-i formed in upper surface 15 therein. Alternately, wood or other materials can be used. The radii and circumferences of the semi-circular grooves 14 a-i can be between any size as desired such as between 1" and 16". In the drawings groove 14a has a 6" radius, groove 14b has a  $5\frac{1}{2}$ " radius, groove 14c has a 5" radius, groove 14d has a  $4\frac{1}{2}$ " radius, 14e has a 4" radius, groove 14f has a  $3\frac{1}{4}$ " radius, groove 14g has a 3" radius, groove 14h has a  $2\frac{1}{2}$ " radius, and groove 14i has a 2" radius. The center of each semi-circle is on a common line 16. A grid pattern of lines 18 and 20 are provided. Lines 20 are tangent to the curves at the common vertical centerline 16 of the curves, and thus are perpendicular to the common vertical centerline 16. Lines 18 are tangent to the curves at points 90 degrees and 180 degrees rotated from the vertical centerline 16, and are parallel to the vertical centerline 16. The plurality of lines 18 and the plurality of lines 20 are at some fixed distance apart from each other, such as  $\frac{1}{4}$ " to  $\frac{1}{2}$ ". The lines of grid pattern 18 and 20 further extend on the scoring plate beyond the curves and are used to help orient the card stock being scored correctly on the scoring plate 12 so that the curved scoring line is correctly placed. X axis (vertical) indicator markings 22 and curve diameter indicator markings 24 are formed on scoring plate 12 (such as in inch measurements.) A pair of protrusions 26 are optionally located on scoring plate 12 and extend above upper surface 15 for use with an optional scoring template, as will be discussed below. Protrusions 26 can be cylindrical plugs. For purposes of forming straight score lines as may be required, an elongate straight groove 28 can be formed on scoring plate 12 and can preferably be about 0.3175-0.476 mm ( $\frac{1}{8}$ " to  $\frac{3}{16}$ ") wide and about 0.3175-0.476 mm ( $\frac{1}{8}$ " to  $\frac{3}{16}$ ") deep.

Referring to FIG. 3, a top plan view of a first optional scoring template overlay portion 30 is shown. Scoring template overlay portion 30 is preferably formed of sheet plastic or metal 32 into which a series of slots 34a-i are formed. In the case of scoring template overlay portion 30, it is adapted for forming semicircular scoring lines, and thus has a series of semi-circular slots 34a-i. For ease of use, the inventor has found that tough, clear plastic, for example, about 0.238-0.3175 mm ( $\frac{3}{32}$ " to  $\frac{1}{8}$ ") in thickness, with slots 34a-i being about 0.3175-0.476 mm ( $\frac{1}{8}$ " to  $\frac{3}{16}$ ") wide to accept a scoring tool will function well. Diameter size indicator markings 36 are preferably placed on sheet 32 adjacent to slots 34a-i. Likewise, X axis indicator markings 38 can be placed on sheet 32 as well. If desired, a grid pattern of lines 40 and 42 to form squares can be placed on template 32, such as by printed lines and the like. The grid pattern of lines 40 and 42 further extend on the template overlay portion 30 beyond the slots 34a-i and are used to help orient the template overlay portion 30 on the card stock being scored. For purposes of forming straight score lines, straight slot portion 44 is preferably formed in template. A

pair of apertures 46 are preferably formed in optional scoring template overlay portion 30 and are sized slightly larger than protrusion 26 positioned on scoring plate 26. The purpose of apertures 46 is to allow optional scoring template overlay portion 30 to be aligned such that its semi-circular slots 34a-i align with semi-circular grooves 14-i in plate portion 10. Used in combination, scoring plate 10 and scoring template overlay portion 30 make forming curved score lines much easier. Although as shown in the figures as semi-circular grooves and slots in scoring plate and overlay template, respectively, the grooves and slots can assume other shapes, such as oval, elliptical, parabolic, or irregular shapes.

Turning to FIG. 4, a view of a scoring tool 50 is shown. Scoring tool 50 has a handle 52 with a scoring tip 54 which is rounded and free from sharp edges to avoid cutting the sheet material to be scored. Scoring tip 54 is sized to be smaller than slots 34a-i formed in overlay template 30 and grooves 14a-i in scoring plate 10.

A user wishing to form curved score lines in sheet material 60, for example, such as cardstock or plastic material with a thickness of about 0.635 mm (0.025"), will decide what the shape and relative position of the score lines should be. For complex curves, the curve can be transferred with pencil and the like to the surface of the material to be scored, if desired. The sheet material 60 to be scored will then be laid on scoring plate 10 such that the grooves are properly oriented relative to the sheet material 60. As shown in FIG. 1, the optional scoring template overlay portion 30 may be laid on top of sheet material 60, and with its apertures 46 over protrusions 26, thereby lining up slots 34a-i of overlay template 30 with grooves 14a-i of scoring plate 10. The user will then take scoring tool 50 and place it in the selected slot (or directly on sheet material if no overlay portion 30 is used), and bear down to score sheet material 60. A scoring line will thus be formed in the desired position on the card stock 60. Depending on the sheet material being used, the scoring pressure necessary will vary. However, by adjusting the pressure applied to the scoring tool, a user can quickly get the feel to make proper score lines. Use of the optional scoring template overlay portion 30 will prevent scoring tool 50 from causing scoring anywhere else other than the desired position, and accurate scoring lines can thus be formed.

Having described the various parts of the device, its use in forming a pillow box 58 is now summarized with respect to FIGS. 5-8. By way of example for use in forming a pocket box with a length of 10" and width of approximately 6" and a depth (or thickness) of 2", with two side cylindrical sections with a 5" radius when viewed along a long axis of the box, the device of the invention can be used as follows.

1. A piece of cardstock 60 is provided in the size of 10" (the length) by 13" (twice the width plus one inch for an overlap seam).
2. The cardstock is scored with score lines parallel to the 10" edge at 6" and 12", 62 and 64, respectively. This essentially defines three panels; those three being the two sides of the box 66a and 66b—each 10" by 6", and the 1" wide overlapping seam panel 68. This can be accomplished by overlaying the cardstock 60 on scoring plate 10 positioned over elongate slot 28. If desired, the optional template overlay portion 30 can be positioned over scoring plate 10 such that elongate slot 44 is directly over elongate groove 28 and elongate straight score 62 and 64 can be formed as desired.
3. Each of the side panels are scored at each end using the 5" radius semicircular scoring groove 14c by laying the

cardstock 60 on scoring plate 10, and optionally laying scoring template aligned with scoring slot 34c so that the short (6") edge of each panel is tangent to the 5" radius scoring slot 34c and directed inwardly into the cardstock 60 in a convex manner, and the long edge is parallel to the scoring lines which are parallel to the centerline of the scoring slots, and the score line 70 is convex toward the end of the panel. Such a score line 70 is formed at the end of each side 66 of the box to be formed.

4. Each side panel 66a and 66b is now scored at each end using the same scoring slot 34c, but lining up the cardstock 60 so the score line 72 is convex toward the center of panels 66a and 66b. This will yield football-shaped sections 74 at each end of both side panels 66a and 66b. These areas will become the ends 74 of the pillow box 60.
5. The cardstock areas 76 outside of the football-shaped sections 74 at the end of each side panel 66a and 66b are cut off with scissors or a craft knife and discarded.
6. The football-shaped sections are folded inwards back and forth along the score lines 72 to soften the material for final folding along these lines later.
7. The 1" by 10" seam panel 68 is flexed back and forth along score line 64 to make score line 64 adjacent to it pliable. It is then folded back toward the inside of the box so it lies flat against the inside of the opposite side panel 66a. It is then attached to the inside of the panel 66a with glue, adhesive or double-sided tape.
8. The pillow box 58 is essentially complete at this point. All that is required is to fold the four football-shaped sections 74 inwardly where they will lock in place, being held there by tension in the folds 72 and friction between the football-shaped sections 74 and the side panels 66a and 66b, forming the pillow box 58 as shown in FIGS. 7 and 8.

The combination of the length, width, and thickness of the pillow boxes made as described above are fixed by the length and width of the cardstock being used. The radius of the scoring slot chosen determines the thickness of the box. Larger radii will result in thinner boxes. It is anticipated that the manufacturer of the kit will provide a chart showing the final finished pillow box dimensions using various cardstock sizes and scoring slot radii.

In addition to being used to form pillow boxes, the scoring templates of the invention can be used to make other scored items having curved scoring lines as part of their design, such as toys, models, and artwork of various kinds, just to name a few. The device can also be used to form embossed designs on boxes, models and artwork.

The drawings and the foregoing description are not intended to represent the only form of the invention in regard to the details of this construction and manner of operation. In fact, it will be evident to one skilled in the art that modifications and variations may be made without departing from the spirit and scope of the invention. Although specific terms have been employed, they are intended in a generic and descriptive sense only and not for the purpose of limitation, the invention being delineated with respect to the following claims.

I claim:

1. A device for forming straight and curved score lines sheet material, comprising:  
a scoring plate comprising a plate having a top surface with a plurality of spaced apart curved grooves formed on the top surface thereof, each of the plurality of

spaced apart scoring grooves having different radii of curvature, each scoring groove having a width and depth; 5

an overlay template portion comprising a plurality of spaced apart curved slots formed therein, wherein the overlay template portion is adapted to overlay the scoring plate and the plurality of spaced apart curved slots are aligned with the grooves on the scoring plate when placed thereon; and

10 a scoring tool with a tip, wherein the tip of the scoring tool is sized to be slideably received in a scoring groove.

2. The device of claim 1, further comprising an elongate straight groove formed on the scoring plate.

3. The device of claim 2, further comprising an elongate straight slot formed through the overlay template that is 15 aligned with the elongate straight groove formed on scoring plate.

4. The device of claim 1, where a grid pattern of guide lines is formed on scoring plate for use in helping to properly align sheet material for scoring on the device. 20

5. The device of claim 1, wherein the plurality of spaced apart curved grooves are semi-circular in shape.

6. The device of claim 1, where a grid pattern of guide lines is formed on overlay template portion for use in helping to properly align sheet material for scoring on the device. 25

7. The device of claim 1, further comprising means to align the template overlay portion with the scoring plate, such that the slots align with the scoring grooves.

8. The device of claim 7, wherein the means to align the template overlay portion with the scoring plate such that the slots of the overlay template are aligned with the scoring grooves of the scoring plate comprises protrusions formed on the scoring plate with complementary and aligned apertures formed through the template overlay portion. 30

9. A device for forming straight and curved score lines in sheet material, comprising:

a scoring plate comprising a plate having a top surface with a plurality of spaced apart curved grooves formed on the top surface thereof, each of the plurality of spaced apart scoring grooves having different radii of curvature, each scoring groove having a width and depth;

an overlay template portion comprising a plurality of spaced apart curved slots formed therein, wherein the overlay template portion is adapted to overlay the scoring plate and the plurality of spaced apart curved slots are aligned with the grooves on the scoring plate when placed thereon;

means to align the template overlay portion with the scoring plate, such that the slots align with the scoring grooves; and

a scoring tool with a tip, wherein the tip of the scoring tool is sized to be slideably received in a scoring groove. 20

10. The device of claim 9, wherein a grid pattern of guide lines is formed on overlay template portion for use in helping to properly align sheet material for scoring on the device.

11. The device of claim 10, wherein a grid pattern of guide lines is formed on scoring plate for use in helping to properly align sheet material for scoring on the device. 25

12. The device of claim 11, wherein the plurality of spaced apart curved grooves are semi-circular in shape.

13. The device of claim 11, further comprising an elongate straight groove formed in the scoring plate and a slot formed through the overlay template that is aligned with the elongate straight groove formed on scoring plate. 30

\* \* \* \* \*



US006139049A

**United States Patent** [19]**Gallagher**[11] **Patent Number:** **6,139,049**[45] **Date of Patent:** **Oct. 31, 2000**[54] **AIR BAG TEAR SEAM AND METHOD OF MANUFACTURE**

[56]

**References Cited****U.S. PATENT DOCUMENTS**

5,358,986	10/1994	Onofusa et al.	.....	524/284
5,744,776	4/1998	Bauer	.....	219/121.7
5,776,566	7/1998	Mace et al.	.....	428/34.5
5,882,572	3/1999	Lutze et al.	.....	264/400
5,883,356	3/1999	Bauer et al.	.....	219/121.62
5,961,143	10/1999	Hlywka et al.	.....	280/728.3

[75] **Inventor:** Michael J. Gallagher, Manchester, N.H.[73] **Assignee:** Textron Automotive Company Inc., Troy, Mich.[21] **Appl. No.:** 09/482,133[22] **Filed:** **Jan. 12, 2000****Related U.S. Application Data**

[62] Division of application No. 09/051,834, filed as application No. PCT/US96/17947, Nov. 8, 1996, Pat. No. 6,062,590.

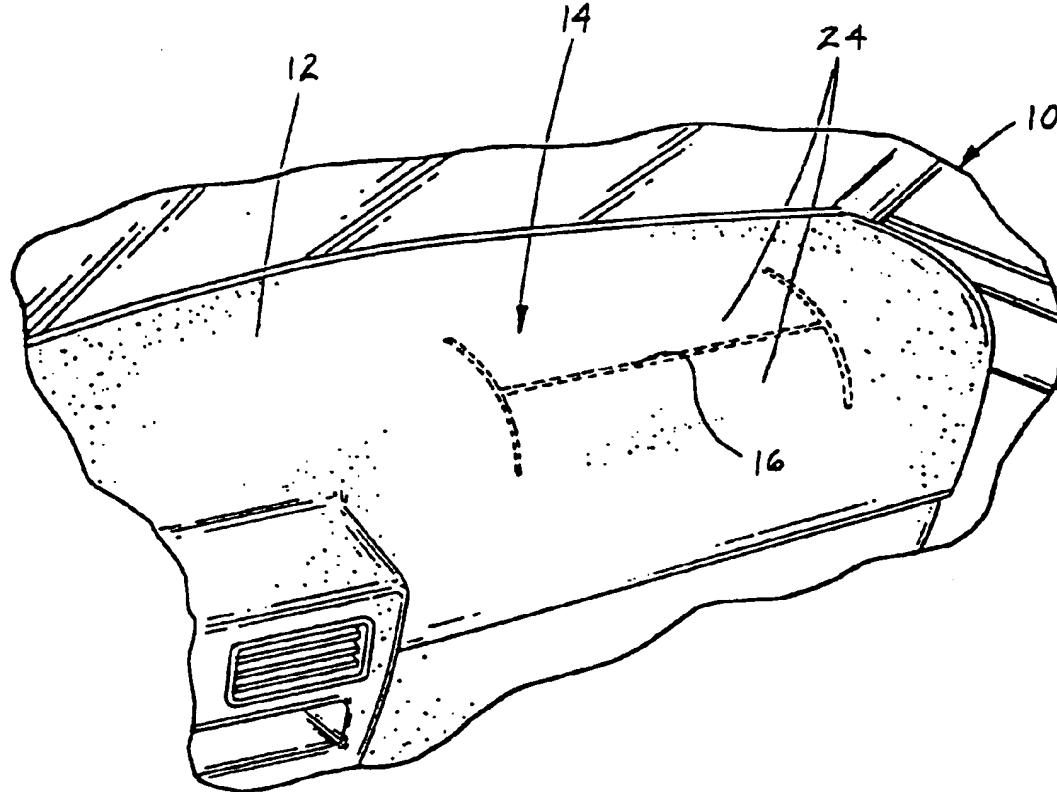
[60] Provisional application No. 60/006,404, Nov. 9, 1995.

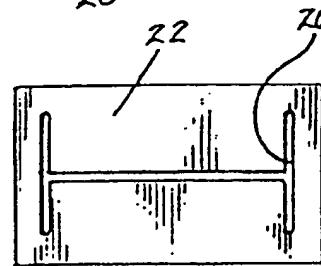
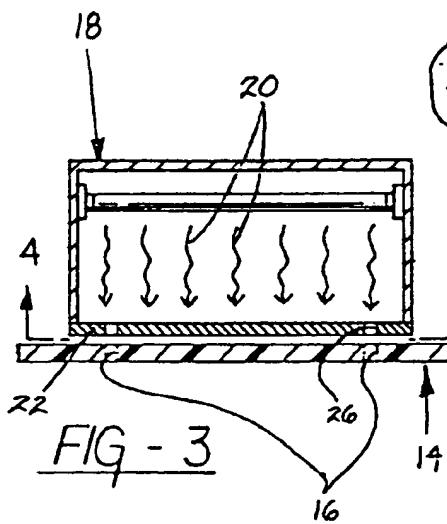
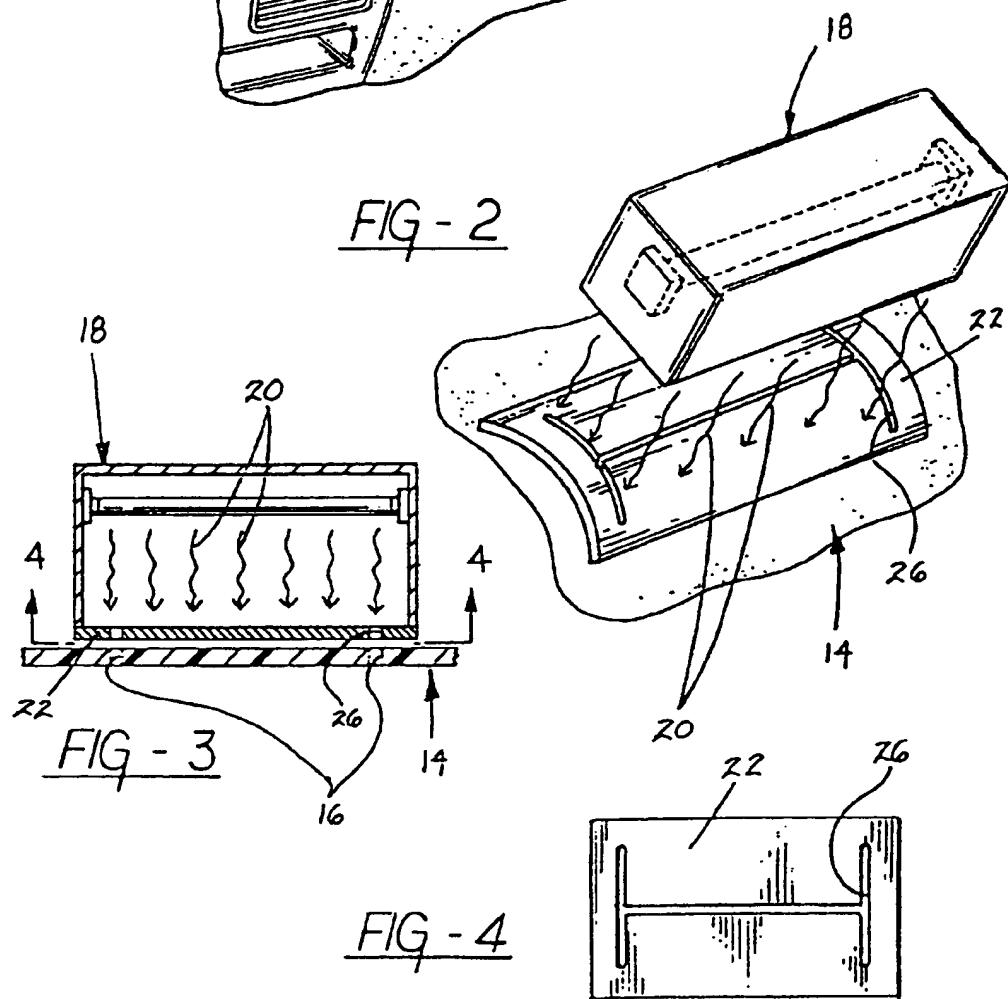
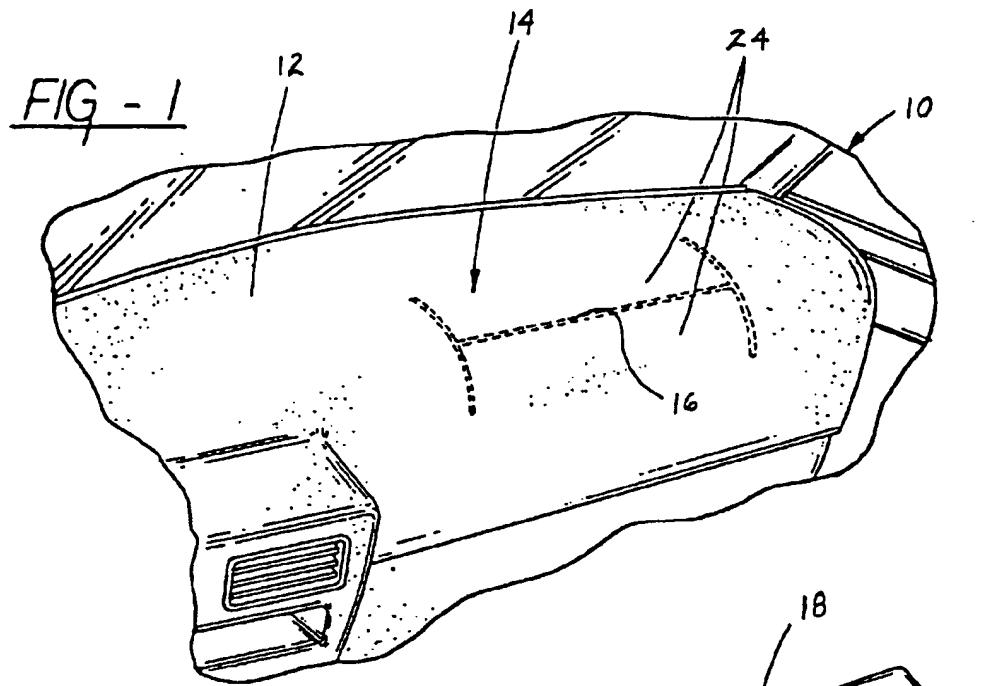
[51] **Int. Cl.<sup>7</sup>** ..... B60R 21/20[52] **U.S. Cl.** ..... 280/728.3; 280/732; 219/121.69; 219/121.71; 219/121.85[58] **Field of Search** ..... 280/728.1, 728.3, 280/730.2, 732; 219/121.69, 121.71, 121.85; 264/446, 494**Primary Examiner**—Eric Culbreth**Assistant Examiner**—L. Lum**Attorney, Agent, or Firm**—Reising, Ethington, Barnes, Kisselle, Learman & McCulloch, P.C.

[57]

**ABSTRACT**

A method for manufacture an air bag cover includes providing a cover skin made of a polymeric material and weakening a seam region in the skin by selective exposure to ultraviolet light.

**13 Claims, 1 Drawing Sheet**



## AIR BAG TEAR SEAM AND METHOD OF MANUFACTURE

This is a division of application Ser. No. 09/051,834, filed on Sep. 21, 1998 now U.S. Pat. No. 6,067,590 which is a 371 of PCT/US96/17947 filed Nov. 8, 1996.

This application claims benefit of Provisional application Ser. No. 60/006,404 filed Nov. 9, 1995.

### TECHNICAL FIELD

This invention relates generally to automotive air bag door tear seams and, more particularly, to chemically weakened tear seams.

### BACKGROUND OF THE INVENTION

Tear seams for air bag door covers are currently produced by a number of different methods. One technique is to mold a thinned section into the cover during its manufacture. This method provides a designed-in, relatively weaker tear seam region along which the cover separates in response to air bag deployment. However, molded-in tear seams of this type have a tendency, over time, to show-through as a visible depression on the outer class A surface of the cover. Vehicle occupants can, therefore, see the pattern of the tear seam in the outer surface of the cover.

The tear seam may also be produced after molding the air bag cover skin, i.e., in a "post-molding operation", by scoring the skin with a knife, hot tool, laser, or other instrument to produce a thinned section in the pattern of a tear seam. However, such post molding operations are costly and must be carefully controlled.

Still another way to produce a weakened tear seam is to form the tear seam region from a weaker material than the rest of the air bag cover skin is formed from. Methods of this type are disclosed in U.S. Pat. Nos. 5,530,057 and 5,567,375, both assigned to the assignee of the present invention. Each of these patents disclose a casting process for forming an integral tear seam from plastic powder. Unlike the plastic powder used to form the rest of the cover skin, the plastic powder cast to form the tear seam region includes a "filler" material such as glass or carbonate. The resulting mixture has significantly less tensile strength than the plastic powder cast to form the rest of the cover skin. However, this method adds steps and cost to the manufacturing process.

It is desirable, when constructing an air bag door cover, to use a cover skin material that can withstand the harmful effects of extended exposure to solar radiation in the ultraviolet portion of the electromagnetic spectrum. Polymeric materials commonly used in forming air bag cover skins are subject to a phenomenon known as photodegradation caused by exposure to UV radiation and oxygen. Photodegradation comprises two distinct chemical processes that together result in chain scission and/or crosslinking in polymer molecules, i.e., the breakage of polymer bonds. In the first of the two processes, photolysis, a polymer absorbs UV radiation which breaks molecular bonds within the polymer forming free radicals. In the second process, autoxidation, the free radicals interact with oxygen to form peroxy radicals.

When polymeric materials are "weathered" in this manner, a strong change in morphology results which affects the mechanical behavior of the polymer. For example, the density and crystallinity of the polymer typically increase while its molecular weight and surface roughness decrease. This results in polymer embrittlement which correspondingly reduces the tensile strength and/or the percent elonga-

tion measured "at the break," i.e. at the point when the material breaks under a tensile load.

Photodegradation can be controlled or eliminated by including UV stabilizers or "inhibitors" which prevent these chemical reactions from occurring. UV promoters are also available that can actually accelerate these chemical reactions. Both UV inhibitors and promoters may be formulated to act only within a desired wavelength range.

UV inhibitors are generally formulated to inhibit UV light in the wavelength range from 320 to 390 nanometers—the so-called "UV-A" range where the ozone layer absorbs very little solar UV radiation. UV inhibitors may also be formulated to cover the wavelength range from 280 to 320 nanometers—the "UV-B" range where most, but not all solar UV radiation is absorbed in the ozone layer. Within the wavelength range from 150 to 280 nanometers, i.e., the "UV-C" range, the ozone layer absorbs practically all solar UV radiation with peak ozone absorption occurring at approximately the 250 nanometer wavelength.

What is needed is a simple, cost effective means of producing an air bag cover having tear seam that is both cost effective to produce and visually undetectable on the outer class A surface of an air bag cover skin.

### SUMMARY OF THE INVENTION

In accordance with this invention, an air bag cover is produced that includes an air bag cover skin made from plastics material susceptible to photodegradation. At least one side of the cover skin is then exposed, under controlled conditions, to light radiated from a light generator. The exposure to light degrades and weakens the cover skin in a selected tear seam region corresponding to the tear seam to be produced. The rest of the cover skin, i.e., the non-tear seam region, is shielded or masked from the light. A tear seam produced in this manner is visibly undetectable to the occupants of the vehicle and less costly to produce.

According to one aspect of the present invention the air bag cover skin includes a compound formulated to promote photodegradation of the cover skin polymeric material. These compounds, known as "UV promoters", increase the rate of photodegradation in the tear seam region which reduces the time and the amount of energy required to effectively photodegrade the polymeric material of the tear seam region of the cover skin.

According to another aspect of the present invention the polymeric material of the air bag cover skin includes UV inhibitors formulated to inhibit UV radiation having wavelengths greater than 320 nanometers. The UV inhibitors protect the cover skin from long-term photodegradation due to solar UV radiation. The UV inhibitors may be formulated to inhibit only UV radiation having wavelengths greater than 280 nanometers.

According to another aspect of the present invention a method is provided for manufacturing the air bag cover skin described above. The air bag cover skin is first formed from a polymeric material. The non-tear seam region of the air bag cover skin is then masked-off and illuminated with electromagnetic radiation of sufficient intensity and within a range of wavelengths that will weaken the polymeric material of the air bag cover skin. The air bag cover skin is illuminated in this manner until the electromagnetic radiation has weakened the polymeric material of the unmasked tear seam region.

According to another aspect of the present invention, the non-tear seam region is masked by placing a template over the air bag cover skin surface to be irradiated. The template

includes an opening having a pattern corresponding in size and shape to the tear seam pattern.

According to another aspect of the present invention, the masking template is included in a single apparatus with the light generator. The template portion of this template-lamp apparatus is then placed directly on the air bag cover skin surface to be irradiated.

According to another aspect of the present invention, the light generator produces no light in the infrared spectrum. This reduces the amount of heat energy imparted to the cover skin and allows the light generator to be placed much closer to the irradiated surface of the air bag cover skin without softening and deforming the skin. The light may be further restricted to include only ultraviolet light to achieve a greater amount of degradation for the amount of energy used.

According to another aspect of the present invention, the cover skin is illuminated within an illumination range including only a portion of the ultraviolet spectrum. In addition, UV inhibitors are included in the polymeric cover skin material and are specifically formulated to inhibit UV radiation outside the illumination range. This allows the UV inhibitors to prevent long-term solar UV photodegradation without inhibiting intentional photodegradation in the illumination range. The illumination wavelength range may be restricted to less than 320 nanometers where most solar UV radiation is absorbed in the ozone layer or may be further limited to less than 280 nanometers where the ozone layer absorbs almost all UV radiation. Correspondingly, UV inhibitors may be formulated to inhibit UV radiation greater than 320 nm and 280 nm, respectively.

Those in the plastics industry normally consider photodegradation to be detrimental to the properties of polymers. This is because photodegradation causes polymer bonds to break which chemically weakens the material. The usual practice is to combat photodegradation by adding ultraviolet (UV) stabilizers, i.e., UV inhibitors, to the material. UV inhibitors lessen, or altogether eliminate, the damaging effects of UV radiation. This invention, to the contrary, recognizes photodegradation as an attribute and uses it, under controlled conditions, to produce the tear seam in the polymer air bag cover skin.

#### BRIEF DESCRIPTION OF THE DRAWINGS

To better understand and appreciate the invention, refer to the following detailed description in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of a vehicle dash board having an air bag door cover portion concealing a passenger side supplemental inflatable restraint (SIR) air bag system;

FIG. 2 is a diagrammatic view showing one method of preparing a tear seam according to the present invention;

FIG. 3 is a diagrammatic view showing an alternative method of preparing the tear seam according to the invention; and

FIG. 4 is a view taken along lines 4—4 of FIG. 3.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to a more detailed description of the invention, FIG. 1 illustrates the interior 10 of an automobile having an instrument panel or dash board 12 of known construction. The dash board 12 is provided with an air bag cover skin portion 14 formed with a weakened tear seam 16. The tear seam 16 overlies and conceals a supplemental

inflatable restraint (SIR) air bag system (not shown) that is mounted beneath the instrument panel 12 and which is operative in a known manner to deploy into the interior compartment 10 of the vehicle through an air bag escape breach formed through the air bag cover skin 14 when the tear seam 16 tears.

The invention is also applicable to driver side-type air bag applications (not shown) in which an inflatable air bag is housed within the steering wheel assembly of the vehicle and concealed by similar cover material having a designed-in tear seam for deploying an air bag and made according to the same photodegradation process. The invention is also applicable to cover skin materials for both "soft" products and "hard" products. In soft products the cover skin material is a separate layer from any underlying support structure. In hard products the cover skin material and any underlying support structure are one and the same, i.e., they are formed together as a single unitary piece.

The cover 14 is fabricated from a suitable polymeric plastics material according to conventional forming techniques known to the art, such as slush molding. Like all polymers, the material used for the cover 14 is susceptible to chemical photodegradation when exposed to ultraviolet light radiation.

Broadly, the invention involves radiating the air bag cover skin 14 in the area that is to function as the tear seam, i.e., the tear seam region 16, from either the front or back surface of the air bag cover skin 14 sufficiently to locally weaken the material and produce a visibly undetectable tear seam 16. FIG. 2 illustrates one method of generating the tear seam 16 according to this invention. A UV radiation device, or "UV generator" 18, is arranged over the one surface of the air bag cover skin 14 and energized to direct UV radiation 20 onto the facing surface of the cover 14. A UV blocking template 22 is arranged between the UV generator 18 and the cover material 14 to block the transmission of the UV radiation 20 to a non-tear seam region 24 of the air bag cover skin 14 except through prescribed openings 26 in the template 22. The openings 26 correspond in size and shape to the tear seam 16 to be produced, i.e., the tear seam region 16 of the air bag cover skin 14. As illustrated, the template openings 26 and tear seam region 16 have a corresponding H-shape, but this is just one pattern of many different patterns that can be employed. Other patterns contemplated include, but are not limited to, "X" and "C"-shaped tear seam patterns. The template 22 may comprise a panel made of metal, wood, or other material that would serve to block UV radiation transmission to the underlying non-tear seam region 24 of the air bag cover skin 14 while allowing UV radiation transmission through the template opening 26 to the air bag cover skin tear seam region 16.

The photodegradation of the exposed polymeric material 14 can be controlled by controlling the UV exposure time. The time required to achieve a certain degree of material degradation may vary from one cover to another and may depend on such factors as the type of material used for the cover, its thickness, the ambient temperature, the intensity of the UV light, and the irradiance and wave length of the light. The UV light employed preferably has a wave length in the approximate range of 10-340 nm to provide optimum energy. It is also preferable that the UV light generator does not emit UV light outside this preferred range. More preferably, the UV generator 18 emits no electromagnetic radiation in the infrared portion of the electromagnetic spectrum, i.e., 0.002 cm-0.02 cm, to minimize or eliminate thermal heat generation associated with infrared radiation. This enables the UV generator 18 to be placed closer to the

cover 14 during treatment to achieve photodegradation without also causing thermal softening and/or cover deformation.

FIGS. 3 and 4 illustrate a variation of the UV emitting apparatus of FIG. 2 in which the UV blocking template 22 is attached as a bottom panel of a UV generating unit 18 as opposed to being a separate independent piece as shown in FIG. 2. The remaining features and operation, however, are the same as those described above in connection with FIG. 2.

In addition to controlling the UV generator 18, the cover material itself may, through appropriate selection of UV inhibitors and promoters, be formulated to control the susceptibility of the material to photodegradation in the prescribed wave length ranges mentioned above. This is achieved by including appropriate UV inhibitors and/or promoters in the polymeric material of the air bag cover skin 14.

More specifically, a UV generator that emits in only a portion of the UV spectrum may be used to illuminate cover material that includes UV inhibitors formulated to inhibit UV radiation 20 outside that portion of the spectrum. Various formulations of UV inhibitors are commercially available from Ciba-Geigy Corp., Ciba Additives, 7 Skyline Dr., Hawthorne N.Y. 1053-2188.

As an alternative to the use of inhibitors, or in addition to their use, UV promoters may be included in the cover material that enhance the degrading effects of UV light in that portion of the spectrum. UV promoters preferably comprise compounds with double bonds because such bonds are inherently more unstable than single bonds. Because double bonds are more unstable, compounds with double bonds are more susceptible to breakage when exposed to UV radiation. Examples of suitable compounds with double bonds include most natural and synthetic rubbers. Suitable promoters could be non-chemically bonded to a base cover skin material or may be chemically bonded with the base cover skin material, i.e., bonded directly to the "backbones" of the polymer molecules that make up the base cover skin material. Polymers preferred for use as base cover skin materials include vinyl, olefin, olefin elastomers, polycarbonate, acrylonitrile-butadine-styrene (ABS), acrylonitrile-styrene-acrylic, polyester and urethanes.

Illumination wavelengths may also be coordinated with appropriate UV promoters and inhibitors to employ intentional tear seam photodegradation while preventing long-term solar UV degradation of the cover skin 14 as a whole. According to one embodiment of the present invention, the illumination range of the UV generator 18 is restricted to ultraviolet light having wavelengths less than 320 nanometers, i.e., light in the UV-B and UV-C ranges where the ozone layer absorbs most solar UV radiation. The cover material to be illuminated in these ranges includes UV promoters formulated to promote the degrading effects of electromagnetic radiation having wavelengths less than 320 nanometers. The cover material may also include inhibitors formulated to inhibit radiation having wavelengths greater than 320 nanometers, i.e. radiation in the UV-A range. The UV-B and C promoters help to intentionally photodegrade the tear seam region 16 while the UV-A inhibitors prevent long-term cover skin degradation due to solar UV radiation. The UV generator illumination range is restricted to UV-B and UV-C to avoid wasting the energy that would be necessary to produce radiation in the inhibited UV-A region of the ultraviolet spectrum.

According to another embodiment of the present invention, the UV generator illumination range is further

restricted to ultraviolet light having wavelengths less than 280 nanometers, i.e., light in the UV-C range where the ozone layer absorbs the most electromagnetic energy. The cover material to be illuminated by the UV-C radiation includes UV-C promoters formulated to promote the degrading effects of electromagnetic radiation having wavelengths less than 280 nanometers. The cover material may also include inhibitors formulated to inhibit radiation having wavelengths greater than 280 nanometers, i.e. radiation in the UV-A and UV-B ranges. The UV-C promoters help to intentionally photodegrade the tear seam region 16 while the UV-A and B inhibitors prevent long-term cover skin degradation due to solar UV radiation. The UV generator illumination range is restricted to UV-C to avoid wasting the energy that would be necessary to produce radiation in the inhibited UV-A and UV-B regions of the ultraviolet spectrum.

Accordingly, the invention contemplates a method of producing a tear seam 16 in an SIR air bag cover skin 14 prepared from photodegradable plastics material in which a preselected tear seam region 16 of the cover material is weakened by photodegradation. The preferred method for producing such a tear seam 16 is to shield the non-tear seam region 24 of the air bag cover skin material with a UV-blocking template 22. The template 22 used in this process has an opening 26 having a size and shape which corresponds to the size and shape of the tear seam 16. The cover is irradiated with UV light to photodegrade the exposed tear seam region 16 of the air bag cover skin material. The irradiation causes polymer chains in the tear seam region 16 to break and crosslink to a greater extent than those of the air bag cover skin material making up the surrounding non-tear seam region 24. As a result, the polymeric material of the tear seam region 16 is relatively more brittle and weaker than the surrounding polymeric material of the non-tear seam region 24. However, there is no visually discernable difference between the tear seam region 16 and non-tear seam region 24. In other words, the outer surface, i.e., the outer class A surface, of the air bag cover skin 14 provides no visible evidence that a tear seam 16 exists.

Other embodiments of the invention which accomplish the same function and/or achieve the same result are incorporated herein within the scope of any ultimately allowed patent claims.

The above is an illustrative description of the invention using words of description rather than of limitation. Obviously, many modifications and variations of this invention are possible in light of the above teachings. Within the scope of the claims one may practice the invention other than as described.

What is claimed is:

1. A method for manufacturing an air bag cover skin for an air bag cover, the air bag cover skin comprising a polymeric material and including an inner and an outer surface, a tear seam region, a non-tear seam region surrounding the tear seam region, the polymeric material of the tear seam region being photodegraded to a greater extent than the polymeric material of the non-tear seam region, said method comprising the steps of:

forming the air bag cover skin from a polymeric material; masking the non-tear seam region of the air bag cover skin with a substance generally opaque to wavelengths of electromagnetic radiation that are capable of weakening the polymeric material of the air bag cover skin; illuminating at least one the inner and outer air bag cover skin surfaces with electromagnetic radiation of suffi-

cient intensity and within a range of wavelengths that will weaken the polymeric material of the air bag cover skin; and

continuing to illuminate the air bag cover skin until the electromagnetic radiation has weakened the polymeric material of the unmasked tear seam region.

2. A method for manufacturing an air bag cover as set forth in claim 1 in which said step of masking includes the step of placing a template over the air bag cover skin surface to be irradiated.

3. A method for manufacturing an air bag cover as set forth in claim 1 in which said step of masking includes the step of placing a combination masking template and light generator apparatus over the air bag cover skin surface to be irradiated.

4. A method for manufacturing an air bag cover as set forth in claim 1 in which said step of illuminating includes illumination limited to radiation outside an infrared portion of an electromagnetic spectrum.

5. A method for manufacturing an air bag cover as set forth in claim 1 in which said step of illuminating includes illumination with electromagnetic radiation in an ultraviolet portion of the electromagnetic spectrum.

6. A method for manufacturing an air bag cover as set forth in claim 5 in which said step of illuminating includes illumination within an illumination range generally restricted to include only a portion of the ultraviolet portion of the electromagnetic spectrum and in which said step of forming the air bag cover skin includes the step of including UV inhibitors in the polymeric material formulated to inhibit cover skin photodegradation caused by UV radiation having wavelengths outside the illumination range of wavelengths.

7. A method for manufacturing an air bag cover as set forth in claim 5 in which said step of illuminating includes an illumination range restricted to ultraviolet light having wavelengths less than 320 nanometers.

8. A method for manufacturing an air bag cover as set forth in claim 5 in which said step of illuminating includes the step of illuminating in an illumination range restricted to ultraviolet light having wavelengths less than 280 nanometers.

9. A method for manufacturing an air bag cover as set forth in claim 6 in which said step of forming the air bag cover skin includes the step of including a compound in the polymeric material which promotes cover skin photodegradation caused by UV radiation having wavelengths within the illumination range of wavelengths.

10. A method for manufacturing an air bag cover as set forth in claim 7 in which said step of forming the air bag cover skin includes the step of including a compound in the polymeric material which promotes cover skin photodegradation caused by UV radiation having wavelengths less than 320 nanometers.

11. A method for manufacturing an air bag cover as set forth in claim 7 in which said step of forming the air bag cover skin includes the step of including UV inhibitors in the polymeric material formulated to inhibit cover skin photodegradation caused by UV radiation having wavelengths greater than 320 nanometers.

12. A method for manufacturing an air bag cover as set forth in claim 8 in which said step of forming the air bag cover skin includes the step of including a compound in the polymeric material which promotes cover skin photodegradation caused by UV radiation having wavelengths less than 280 nanometers.

13. A method for manufacturing an air bag cover as set forth in claim 8 in which said step of forming the air bag cover skin includes the step of including UV inhibitors in the polymeric material formulated to inhibit cover skin photodegradation caused by UV radiation having wavelengths greater than 280 nanometers.

\* \* \* \* \*



US005744776A

## United States Patent [19]

Bauer

[11] Patent Number: 5,744,776

[45] Date of Patent: Apr. 28, 1998

[54] APPARATUS AND FOR LASER  
PREWEAKENING AN AUTOMOTIVE TRIM  
COVER FOR AN AIR BAG DEPLOYMENT  
OPENING

[75] Inventor: David J. Bauer, West Bloomfield,  
Mich.

[73] Assignee: Tip Engineering Group, Inc.,  
Farmington Hills, Mich.

[21] Appl. No.: 332,565

[22] Filed: Oct. 31, 1994

## Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 132,299, Oct. 5, 1993, Pat. No. 5,375,875, and a continuation-in-part of Ser. No. 151, 175, Mar. 1, 1994, abandoned, which is a division of Ser. No. 934,886, Aug. 24, 1992, Pat. No. 5,217,244, which is a continuation of Ser. No. 471,922, Jan. 23, 1990, abandoned, which is a continuation of Ser. No. 380,156, Jul. 14, 1989, abandoned.

[51] Int. Cl<sup>6</sup> B23K 26/00

[52] U.S. Cl. 219/121.7; 219/121.71;  
219/121.83

[58] Field of Search 219/121.62, 121.83,  
219/121.68, 121.69, 121.7, 121.71, 121.72;  
280/728.3

## [56] References Cited

## U.S. PATENT DOCUMENTS

3,016,464	1/1962	Bailey	219/121.83
3,649,806	3/1972	Konig	
3,909,582	9/1975	Bowen	
3,965,328	6/1976	Locke	
4,038,513	7/1977	Steigerwald	
4,169,976	10/1979	Cirri	219/121.72

4,302,654	11/1981	Bennett et al.	
4,625,093	11/1986	Chryssolouris	
4,639,572	1/1987	Gruzman et al.	
4,865,686	9/1989	Sinohara	
4,959,119	9/1990	Lantzer	
5,001,325	3/1991	Huizinga	219/121.69
5,221,823	6/1993	Usui	
5,250,784	10/1993	Muller et al.	
5,321,227	6/1994	Fuchs et al.	
5,335,935	8/1994	Proos et al.	280/728.3
5,365,032	11/1994	Muller et al.	
5,375,875	12/1994	DeSalvo et al.	280/728.3
5,491,319	2/1996	Economikos et al.	

## FOREIGN PATENT DOCUMENTS

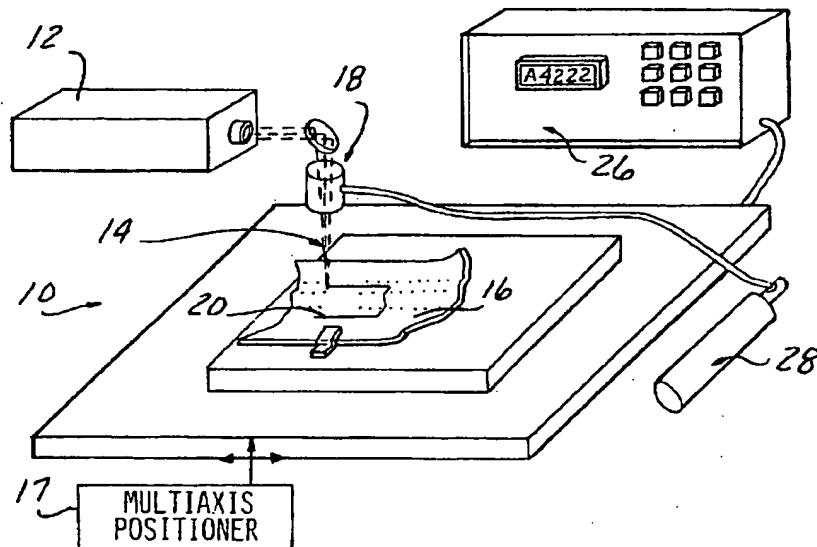
1-210185	8/1989	Japan	219/121.83
2-99324	4/1990	Japan	
2253282	9/1992	United Kingdom	219/121.83
2276354	9/1994	United Kingdom	
9106395	5/1991	WIPO	219/121.62

Primary Examiner—Geoffrey S. Evans  
Attorney, Agent, or Firm—John R. Benefiel

## ABSTRACT

A process for preweakening the inside of an automotive trim piece cover layer of various constructions by use of a laser beam so as to enable formation of an air bag deployment opening in the trim piece formed at the time the air bag deploys. The laser beam impinges the inside surface of the cover to form a groove scoring or spaced perforations to form a preweakening pattern. A robot arm may be used to move a laser generator so as to form the preweakening pattern. The laser beam can be controlled in accordance with sensed conditions to achieve accurate preweakening, and may also be used to trim substrate panels and to perform other cutting operations.

22 Claims, 6 Drawing Sheets



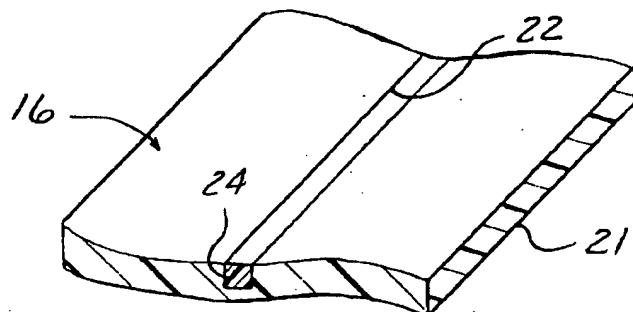
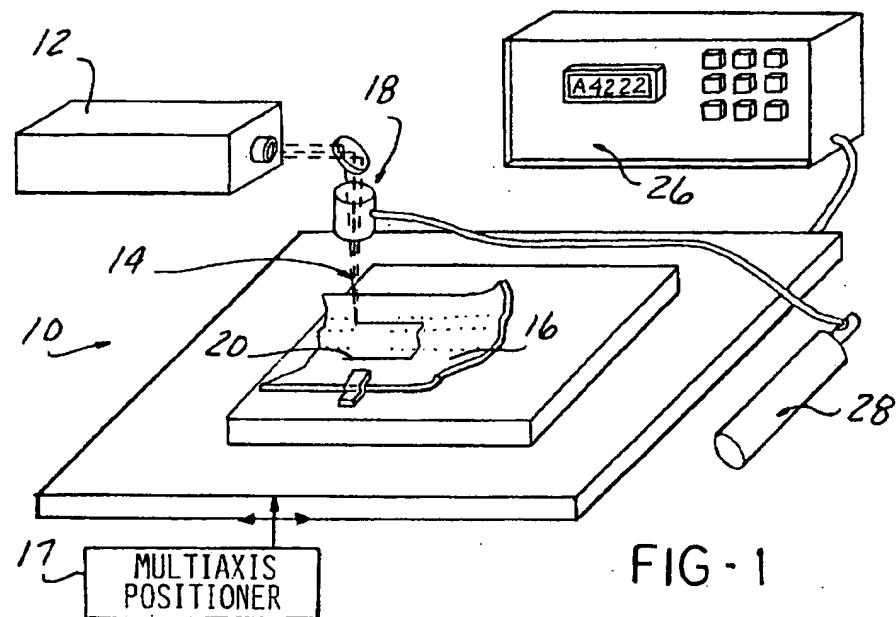


FIG. 2

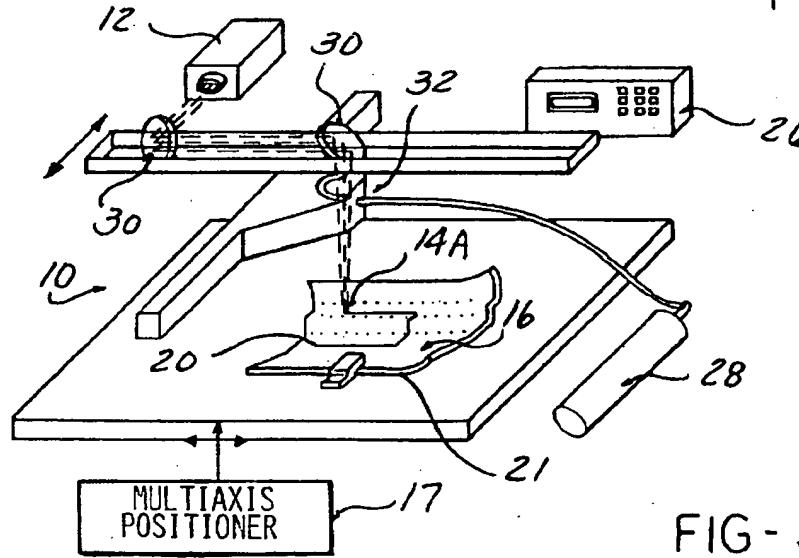


FIG. 3

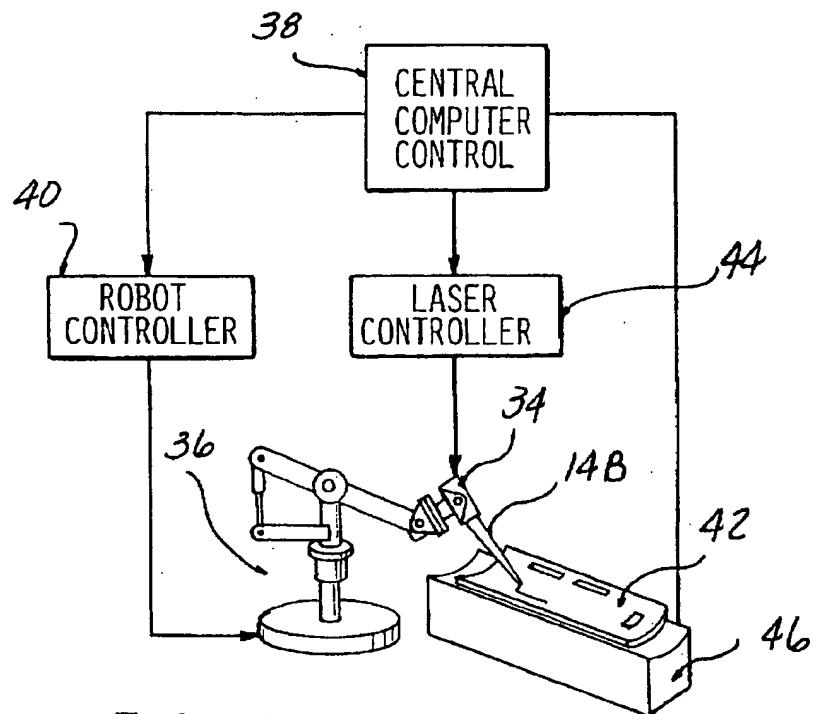


FIG-4

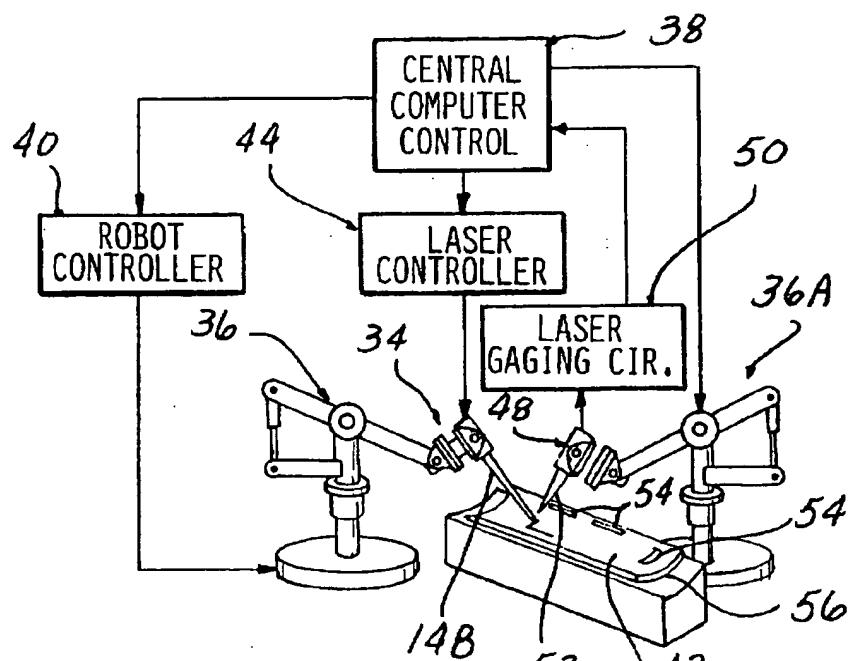


FIG-4A

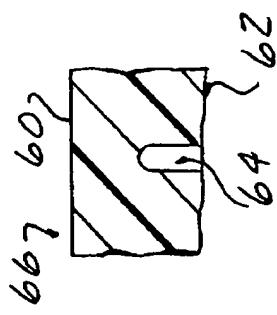
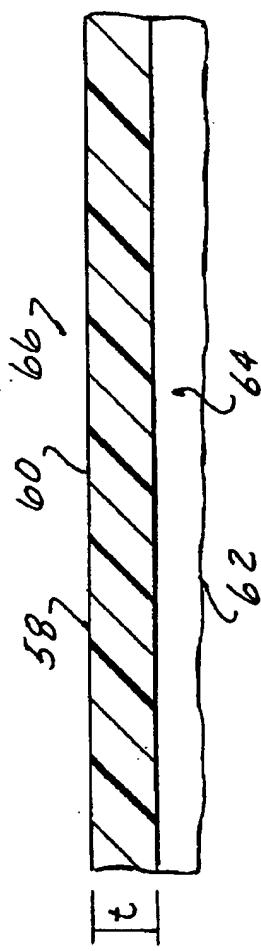


FIG - 5A

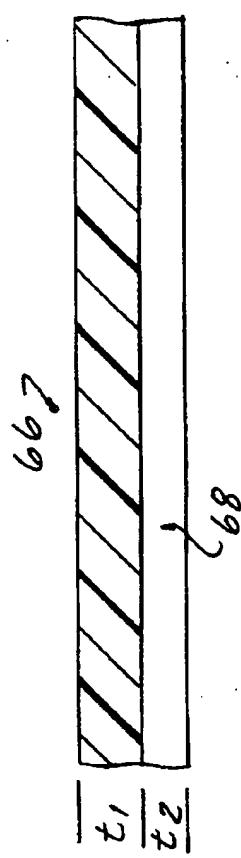


FIG - 6

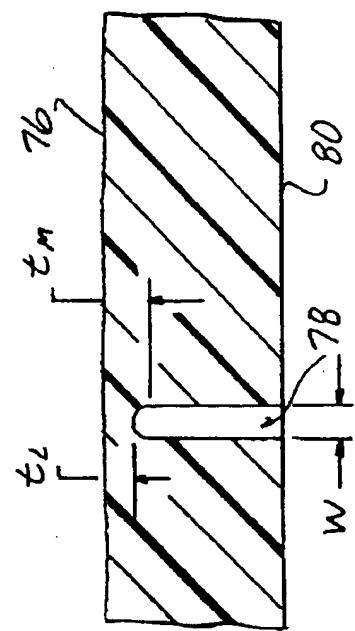
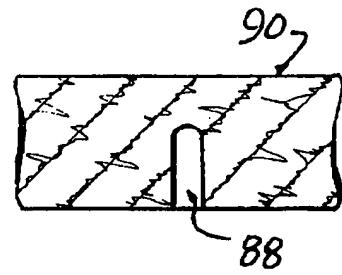
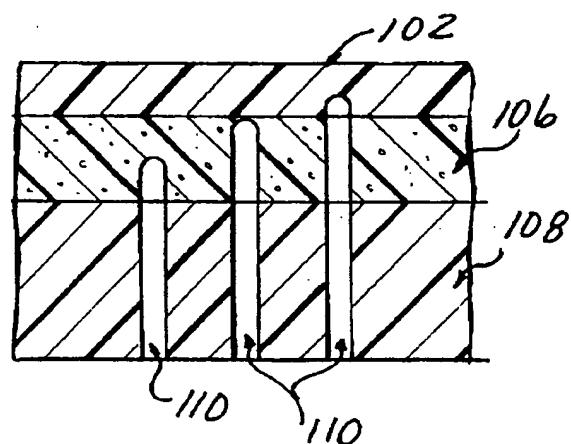
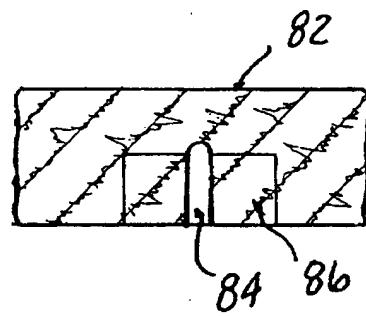
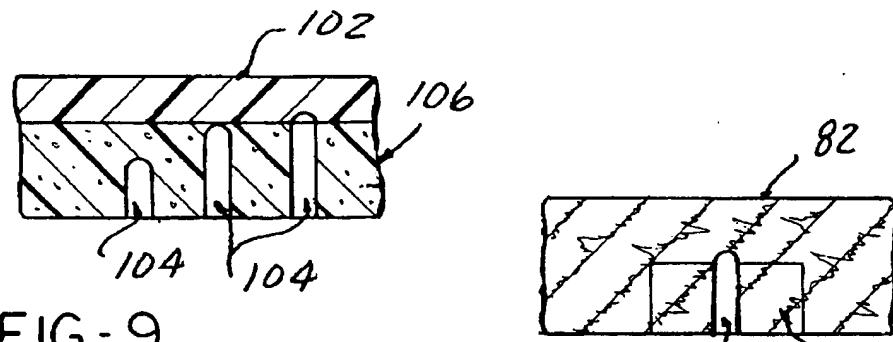
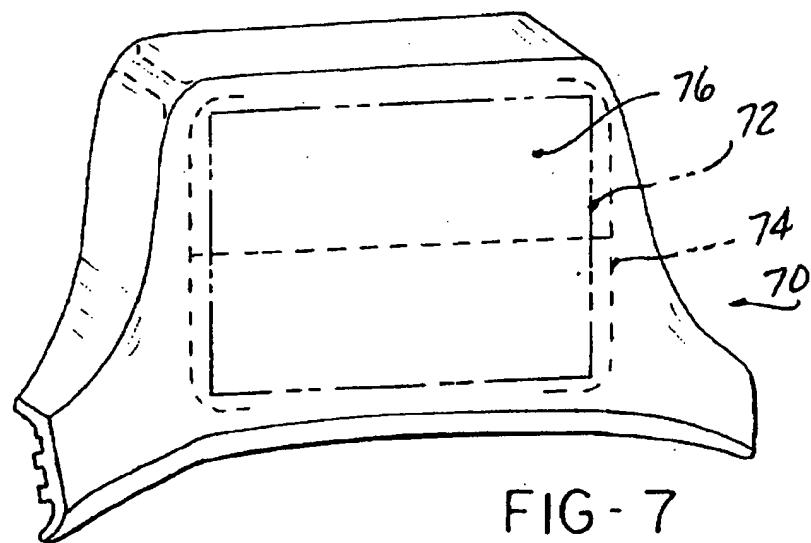


FIG - 8



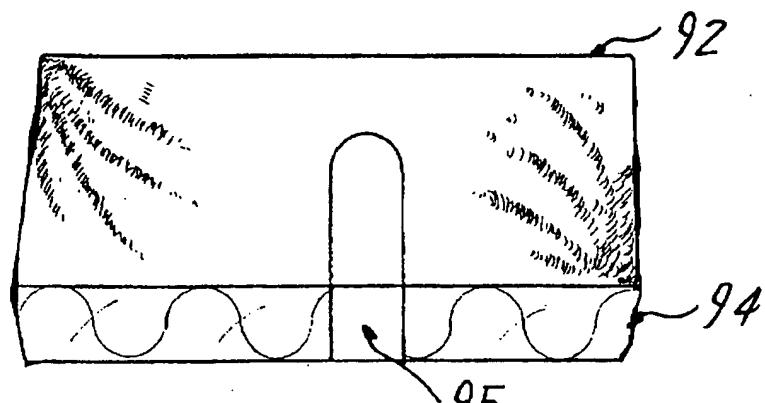


FIG-13

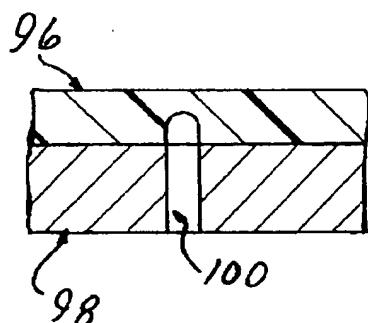


FIG-14

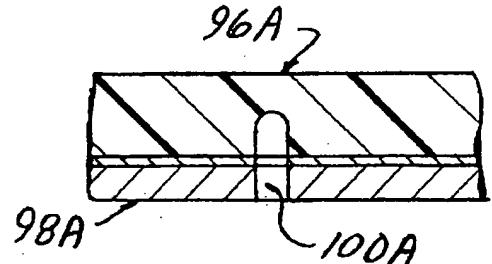


FIG-15

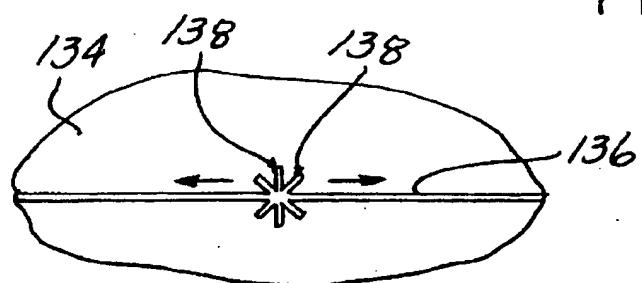


FIG-19

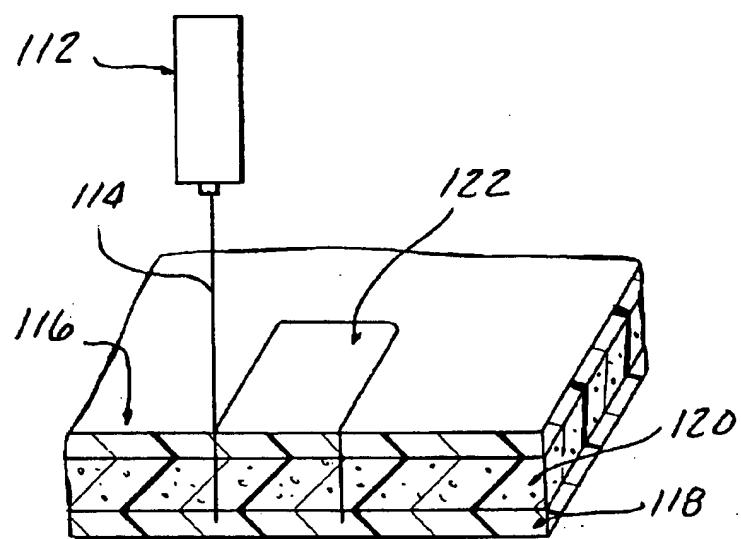


FIG-16

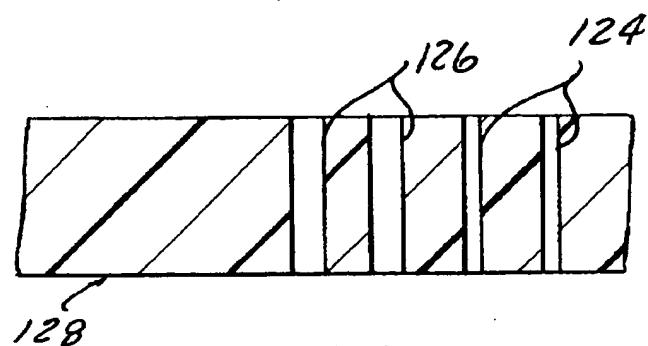


FIG-17

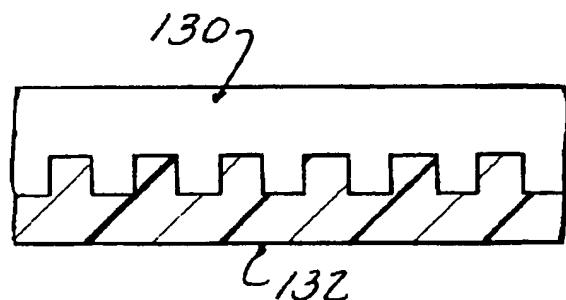


FIG-18

APPARATUS AND FOR LASER  
PREWEAKENING AN AUTOMOTIVE TRIM  
COVER FOR AN AIR BAG DEPLOYMENT  
OPENING

CROSS-REFERENCE TO RELATED  
APPLICATIONS

This application is a continuation-in-part of U.S. Ser. No. 08/132,299, filed on Oct. 5, 1993, now U.S. Pat. No. 5,375,875; a continuation-in-part of U.S. Ser. No. 08/151,175, filed on Mar. 1, 1994, now abandoned, which is a division of U.S. Ser. No. 07/934,886, filed on Aug. 24, 1992, now U.S. Pat. No. 5,217,244, which is a continuation of U.S. Ser. No. 07/471,922, filed on Jan. 23, 1990, now abandoned, which is a continuation of U.S. Ser. No. 07/380,156, filed on Jul. 14, 1989, now abandoned.

FIELD OF THE INVENTION

The present invention concerns cutting and scoring of covers for automotive trim pieces enclosing air bag safety devices.

BACKGROUND OF THE INVENTION

Air bag safety systems have come into widespread use in automotive vehicles and light trucks and have been proposed for use in passenger trains and airplanes.

Such systems comprise an inflatable cushion, commonly referred to as an "air bag" which is stored folded in a storage receptacle and then very rapidly inflated, as with gas from a pyrotechnic gas generator, when a collision of the vehicle is detected by sensors. The air bag is thereby deployed in a position to absorb the impact of the driver or a passenger.

It is necessary that the folded air bag be stored in an enclosed secure environment within the passenger compartment, protected from tampering, and yet be allowed to properly deploy into the passenger compartment as the air bag is inflated.

It is critical that the air bag deploy within milliseconds of activation of the system in order to protect the occupant.

As noted, the air bag is enclosed within a storage receptacle, which is typically mounted behind an interior trim piece, such as a steering wheel cover in the case of the driver's side air bag, or a section of the instrument panel, in the case of the passenger's side air bag. It has been proposed to also provide side impact air bags in the vehicle doors.

One or more air bag deployment doors normally overlie the air bag receptacle and are forced open when the air bag is inflated to allow deployment of the air bag through the opening created by the door panel movement.

As described in U.S. Pat. No. 5,082,310 issued on Jan. 21, 1992 for an "Arrangement for Providing an Air Bag Deployment Opening", a seamless construction is advantageous in which the deployment door panels are not separately delineated within the expanse of the trim piece, but rather a smooth uninterrupted surface is provided extending over the deployment door substrate panels.

This construction necessitates severing portions of the covering of the trim piece in order to allow the door panels to hinge open.

Severing has been achieved by the pressure of the inflating air bag, or by various other methods which have been proposed, such as linear energy devices described in copending U.S. patent application Ser. No. 08/279,225, filed Jul. 22, 1994, attorney docket No. TIP-161. See also U.S. patent

application Ser. No. 08/027,114, filed Mar. 4, 1993, and U.S. Pat. Nos. 5,127,244 and 4,991,878 describing pyrotechnic elements used to cut the outer cover layer of the trim piece.

Cutter blades have also been proposed which are forced outwardly by the air bag inflation to assist in cutting the cover layer, but these outwardly swinging elements can present a potential hazard to a vehicle occupant seated in front of the deployment door.

Automotive interior trim covering materials such as vinyl plastic are relatively tough and difficult to sever, and also a predetermined severing pattern is necessary for proper door panel opening, such that heretofore preweakening grooves have been formed in the trim cover in a predetermined pattern to insure proper opening.

It has heretofore been proposed to provide an "invisible seam" installation in which the deployment door pattern is totally invisible to a person seated in the vehicle passenger compartment, and even faint outlines or "witness" lines are desirably avoided.

Scoring of the covering layer from the inside, if not done accurately, can over time become at least faintly visible from the exterior of the trim piece.

Fabrication of the automotive interior trim pieces with preweakening grooving particularly for invisible seam applications is thus a difficult manufacturing challenge.

First, the groove depth must be carefully controlled in order to achieve reliable rupture of the outer cover at exactly the right time during the air bag deployment event.

If the groove is too shallow, the thickness of the remaining material may be too great, presenting excessive resistance to severing, delaying air bag deployment. Conversely, if too little material remains, over time cracking may be result, or at least allow the appearance of externally visible "witness" lines.

The preweakening effect may also be less effective if the grooves are molded-in during the process since it has been found that cutting into plastic material such as vinyl has a better preweakening effect compared to molding-in the groove during the initial manufacture of the item.

The high pressures used in injection molding can cause a "crazing" effect at the thinned bridging material extending over the gap defined by the groove. This crazed zone is rendered more visible as the part is removed from the mold, particularly if the part is not completely cooled when it is being removed.

The net effect is that the molded groove becomes visible on the exterior side.

It is difficult to accurately and reliably control the depth of mechanical cutting of component materials such as sheet vinyl, since the material is variably compressed by the pressure of a cutting instrument.

U.S. Pat. No. 5,082,310, referenced above, describes a partial cutting procedure which is intended to enable accurate control over the depth of cut into a sheet of pliant plastic material such as a vinyl skin. However, a purely mechanical cutting operation still has other inherent accuracy limitations and is slow to execute.

Also, some cover materials have irregular inside surfaces, i.e., dry powder slush processes create such irregularities. If the groove depth were constant, this results in an irregular thickness of the remaining material. This leads to erratic performance as the resistance to opening pressure will vary greatly.

The groove width is also important, in that if a too narrow groove is cut into many plastics, a "self healing" may occur,

particularly at elevated temperatures in which the groove sides will re-adhere to each other, causing the preweakening effect to be erratic or neutralized.

The required groove width also varies with the notch sensitivity of the material being preweakened.

A further difficulty is encountered in assembling the preweakened component to the interior trim structure so that the lines of preweakening are properly registered with the other components. For example, the vinyl skin in a skin and foam instrument panel must be accurately positioned on the instrument panel substrate and the deployment door substrate panels so that the preweakening lines are stressed as the door edges hinge out under pressure from the air bag.

This alignment requirement creates manufacturing difficulties and increased costs particularly since a variety of forms of instrument panel structures are employed, i.e., skin and foam, vinyl clad, hard plastic with a finished surface, etc., since a variety of forming techniques are employed, i.e., vacuum formed calendered plastic sheet, dry powder slush molded, injection molded, etc. A leather covering layer is sometimes may be used in lieu of a vinyl plastic covering layer.

Accordingly, it is an object of the present invention to provide a process for preweakening trim components overlying an air bag installation by groove scoring which is highly accurate in production implementation, and which may be efficiently integrated into the trim piece manufacture to lower costs and improve results.

#### SUMMARY OF THE INVENTION

According to the invention, the preweakening groove scoring of a smoothly contoured trim piece cover material overlying an air bag receptacle is carried out by the use of a laser beam which is controlled and guided so as to produce grooves of a precise depth and width formed by the laser beam energy into the undersurface of various trim piece cover materials such as a vacuum formed sheet of vinyl.

A sensor provides a feedback signal allowing relative positioning of the workpiece and/or varying of the laser beam source intensity or to precisely control the groove depth to achieve a constant thickness of the remaining material.

The workpiece and laser beam source can be mounted for relative movement in a two-axis positioner table, or alternatively, a system of movable reflectors can optically generate the groove pattern.

A five axis robotic arm can also be used to guide the laser beam source in the required pattern extending in three dimensions, and in process or post-process gaging can also be utilized to correct the laser and robot control and improve results.

The laser beam preweakening groove scoring can be carried out on the cover piece prior to its incorporation into the trim piece or such groove scoring can be carried out after attachment to a substrate or other trim elements grooving the underlying substrate and partially scoring the cover layer at the same time to create a deployment door substrate panel while preweakening the cover material.

The laser beam apparatus can further be utilized to trim the assembled trim piece.

#### DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective diagrammatic view of a laser beam scoring apparatus having a trim piece disposed therein being preweakened in a predetermined pattern by laser beam groove scoring.

FIG. 2 is a fragmentary view of a trim piece having a preweakening groove formed therein back filled with a filler material.

FIG. 3 is a perspective diagrammatic view of another form of the laser beam scoring apparatus according to the invention and having a trim piece disposed therein being preweakened in a predetermined pattern by laser beam groove scoring.

FIG. 4 is a perspective, simplified representation of a preferred robot arm form of the laser beam scoring and cutting apparatus together having a trim piece disposed therein being trimmed and preweakened in a predetermined pattern by laser beam groove scoring.

FIG. 4A is a perspective, simplified view of the robot arm laser beam scoring and cutting apparatus of FIG. 4 with an added robot arm for in-process gaging of the trim piece surface.

FIG. 5 is an enlarged, fragmentary sectional view taken through a dry powder slush molded cover and along a preweakening laser scored groove.

FIG. 5A is a sectional view of the cover of FIG. 5 taken across the preweakening groove.

FIG. 6 is an enlarged, fragmentary sectional view taken through smooth calendered sheet stock, vacuum formed into an air bag installation cover layer, laser scored from the undersurface.

FIG. 7 is a front perspective view of a steering wheel cover which overlies an air bag installation and which has been preweakened in a predetermined pattern with a laser scored grooving.

FIG. 8 is an enlarged sectional view of a portion of the steering wheel cover shown in FIG. 7, the section taken across the laser formed groove.

FIG. 9 is an enlarged sectional view of a vinyl cladding cover material which has been laser scored with grooves of various depths.

FIG. 10 is an enlarged sectional view of a layer of vinyl cladding vacuum formed to a thermoplastic substrate such as for an instrument panel trim piece which has been laser scored with grooves of various depths.

FIG. 11 is an enlarged sectional view of a leather covering material which has been pretreated and subsequently laser scored through the pretreated region.

FIG. 12 is an enlarged sectional view of the leather covering material which has been laser scored without the pretreatment in the region of the scoring.

FIG. 13 is an enlarged sectional view of a cosmetic covering such as a fabric material having a backing layer, preweakened by being laser scored to penetrate the backing layer.

FIG. 14 is an enlarged sectional view of a composite cover comprised of a metal substrate panel with an overlying skin, both preweakened by a laser-formed groove.

FIG. 15 is an enlarged sectional view of molded urethane with a molded-in-place scrim, both preweakened with a laser formed groove.

FIG. 16 is a fragmentary section of a trim piece workpiece in which the substrate is being cut at the same time the covering layer is being scored.

FIG. 17 is a sectional view of a trim piece being preweakened by being perforated with an intermittently generated laser beam.

FIG. 18 is a sectional view of a trim piece being scored to variable depths with a pulsating laser beam.

FIG. 19 is a fragmentary plan view of a laser scored groove with transverse slits added to establish local weakening to control the site at which tearing is initiated.

#### DETAILED DESCRIPTION

In the following detailed description, certain specific terminology will be employed for the sake of clarity, but it is to be understood that the same is not intended to be limiting and should not be so construed inasmuch as the invention is capable of taking many forms and variations within the scope of the appended claims.

The present invention is concerned with preweakening of an automotive interior trim piece such as a steering wheel cover or an instrument panel overlying an air bag receptacle stored behind the trim piece. The surface of the interior trim presented to the passenger compartment must be aesthetically pleasing rather than starkly utilitarian. There has also been developed a preference for eliminating any suggestion of the presence of the stored air bag. In the past, separately defined deployment doors have been fit into an opening in the instrument panel. In the case of a wheel cover, visible delineations segmenting the cover to form deployment doors have been provided.

Internal grooves have also been provided, typically molded into the trim piece itself.

As described above, molded grooves have sometimes resulted in exteriorly visible "witness" lines, since the high injection pressures forcing the plastic through the narrow gap remaining above the groove has resulted in a crazing pattern, as well as slight cracking when the part is removed from the mold.

The present invention comprises the process of laser scoring to obtain the preweakening internal groove after the cover has been molded or otherwise formed.

A laser beam is directed at the cover layer or other trim piece component to score the component along a path defining the desired pattern matching the deployment doors.

The laser scoring has been found to result in elimination of any exteriorly visible lines, even where minimum material remains above the scoring groove.

Referring to a first embodiment (FIG. 1) of a laser scoring apparatus 10 suitable for practice of the invention, a small (25-150 watt) carbon dioxide gas laser source 12 producing a coherent infrared laser output beam 14 at 10.6 micron wavelength is driven to effect controlled scoring of a region of a polymer sheet material instrument panel cover 16 extending over an air bag installation when installed. The cover 16 is moved relative to the laser source 12 to cause tracing of a particular pattern at a precise rate of scoring by a multiaxis positioning system 17. The laser output beam 14 is focussed to a spot or small diameter pencil beam using one or more focussing elements 18 to cause formation of a score line 20 of acceptable width. The presence of the score line 20 which is cut to a significant depth generates a seam which is invisible when viewed from outside face 21 of cover 16 (FIG. 2). The outside face 21 of cover 16 forms the cosmetic surface presented to occupants of the vehicle.

The width of the score line 20 is generally minimized in typical applications but self healing may be avoided when necessary by making wider cuts which may be backfilled with a material having physical properties having generally beneficial physical properties for improving bursting of the invisible seam during air bag operation in the vehicle.

For example and referring to FIG. 2, a portion of a polymer sheet instrument panel cover 16 with a wide score

line 22 and with filler 24 comprising a cured in place silicone rubber bead is shown. Filler 24 provides mechanical support in a similar fashion as was experienced before polymer was removed by the laser. The mechanical support provided by filler 24 prevents deterioration of cover 16 over the lifetime of the vehicle.

Typical focusing elements for infrared laser 12 comprise gallium arsenide or germanium refractive lens members, or gold reflective members. Several alternate laser types will achieve good results and laser source 12 may be an excimer, solid state, argon gas, or diode laser. However, the carbon dioxide laser is likely to be the least expensive in both initial cost and over the required lifetime.

If laser source 12 produces continuous output, the depth of the score line 20 is controlled by the laser output power density at the surface of cover 16 and the rate at which cover 16 moves relative the beam 14.

In another process, laser source 12 may be controlled to generate pulses of a laser output beam, each pulse removing by heat ablation or combustion a minute quantity of cover 16 material. Depth is therefore controlled by applying a particular number of pulses before moving to an adjacent, possibly overlapping, site on the inside of cover 16. The pulsed laser technique combined with a stepwise movement of cover 16 should result in superior control over the process when a computer based controller 26 is used.

Multiaxis positioning system 17 may be driven by a multiplicity of electric motors controlled by a small computerized controller 26 as shown, or alternatively, by electromechanical actuation of a multiplicity of cams and mechanical devices which move the cover 16 in a proper pattern at appropriately controlled rates.

In most industrial applications, the focusing elements 18 must be maintained clean and free of blowback debris emanating from the score line 20. A free flowing gas system 28 is frequently employed to achieve focusing element 18 cleanliness. Also, certain gases, if directed to the score line 20 formed at the laser impingement area, will alter the chemistry and thermodynamics at the scoring site. For example, inert gases such as nitrogen or argon can displace the oxygen in the air at the impingement site and prevent both charring and local combustion while keeping the focusing elements clean. Alternate gases and flow rates can dramatically alter the properties of the resulting score line 20 and create a wide range of physical properties of the cover 16.

FIG. 3 shows yet another embodiment in which the cover 16 is maintained in a fixed position and the laser output beam 14A is manipulated by a system of controlled positioning translating mirrors 30 and a controlled positioning focusing system 32.

FIG. 4 illustrates a preferred form of the invention, in which a self-contained laser generator 34 is mounted to a robot arm manipulator 36, which moves the laser generator 34 under program control stored in a central computer control 38 and directing a robot controller 40, so as to cause a focused laser beam 14B to trace a pattern on a trim piece cover 42 corresponding to a programmed score line.

The computer controller 38 may also be connected to a laser controller 44 which can vary the operation and power level of the laser generator 34.

The cover 42 is fixtured on an ultrasonic sensor 46 which generates signals corresponding to the thickness of material remaining after the groove scoring is produced by the laser beam 14B such as to provide a feedback signal to the central computer control 38 to vary the position of the laser gen-

erator 34 and/or its power output to precisely control the thickness of material remaining after the groove scoring is produced. The resistance to tearing of the remaining material above the groove is important to proper air bag deployment and hence its thickness should be controlled.

Such ultrasonic sensors capable of gaging internal features, such as material thickness, are commercially available, and hence details are not here given.

The laser generator 34 is preferably of the "diffusion cooled" type which does not require gas line hookups and thus is readily mountable to a robot arm manipulator. Accordingly, the optical system is simplified as the beam is directed by robot arm motion, lower costs and improving performance. A more rugged, reliable installation also results, suited to a production environment.

Diamond™ lasers available from Convergent Energy of Sturbridge, Mass. are perfectly suited for this application.

FIG. 4A shows a variation wherein a second robot arm 36A is provided which manipulates a gaging laser beam generator 48, directing and reflecting low power laser beam 52 upon the cover 42, which reflected laser beam is detected and analyzed in a laser gaging circuit 50. From this, there is developed a signal in the laser gaging circuit 50 indicating the precise location of the cover surface at a point just ahead of the cutting laser 14B. This allows the central computer control 38 to cause the position of the cutting laser beam generator 34 to be shifted by the robot arm 36 correspondingly (or to adjust the output beam) so as to maintain a groove depth which will produce a constant thickness of remaining material.

The laser beam can be directed to not only produce the scoring of the cover 42, but may produce cutout openings 54 therein. Further, the perimeter of a substrate panel 56 to which the cover 42 is assembled can be trimmed as well, achieving significant manufacturing economies.

FIGS. 5 and 5A illustrate the application of the above-described process to a cover panel 58 formed by a dry powder slush molding operation. This process is commercially practiced by depositing a powder on a heated mold surface, which results in a smooth outer surface 60, grained and painted, which is exposed within the passenger compartment. The other surface 62 is relatively rough, and hence a relatively varying depth groove 64 is necessary to leave a constant thickness  $t$  of a remaining material. The thickness  $t$  must be controlled to achieve a predictable tearing strength and to avoid any visible indication on the outer surface 60.

Thus, gaging of the thickness  $t$ , as with an ultrasonic gage, is necessary, varying the depth of the groove 64 to maintain the thickness  $t$ .

FIG. 6 shows a segment of a cover 66 vacuum formed from smooth calendered sheet vinyl. In this case, the groove 68 may be of constant depth inasmuch as both surfaces are smooth and the combined thickness  $t_1$  of the groove 68 and  $t$ , the remaining material is constant.

In both examples, the covers 58, 66 are assembled in a mold after scoring with an instrument panel substrate (not shown), foam injected into an intervening space to bond together the substrate and cover, as well as deployment door panels and frame, into a unitary trim piece.

FIGS. 7 and 8 illustrate the process applied to an injection molded wheel cover 70, having an air bag receptacle indicated in phantom at 72, aligned with a preweakening pattern 74 arranged beneath the main outer surface 76, which may be grained and painted, as indicated.

The preweakening pattern consists of a series of laser scored grooves 78 in the inner or rear face 80.

The width  $w$  of the groove is sufficient to avoid self healing. The thickness  $t_L$  of material remaining above the the laser beam scored groove 78 may be less than the remaining thickness  $t_M$  of a molded groove and still remain invisible from the finished surface 76.

It is also noted that the laser scoring process can be carried out very rapidly, and saves processing time over the molding time where a long cooling interval is required to avoid cracking over the thinned out region above the preweakening groove.

The scoring depth can vary from 20%-80% of the total thickness depending on the available tearing force, the strength of the material used, and whether or not other assisting devices are employed.

FIGS. 9 and 10 show the application of the process of vinyl cladding covers. In FIG. 9, an outer vinyl layer 102 is bonded to a polypropylene foam backing layer 106 to form a composite cover. Laser scored grooves 104 extend into the rear face to various exemplary depths, i.e., partially into layer 106, completely through the layer 106, or partially through the covering layer 102. The groove depth required depends on the needs of the particular application, i.e., the level of force designed to cause rupture of the preweakened seam.

In FIG. 10, the vinyl cladding layer 102 and backing layer 106 are vacuum formed and adhesively bonded to a thermoplastic substrate 108. In this case, the laser scored grooves 110 also penetrate the substrate 108.

FIGS. 11 and 12 illustrate the process applied to a leather cover 82. In FIG. 11, a groove 84 is laser scored into a zone 86 which has been pretreated with lacquer to be more notch sensitive as described in detail in copending U.S. application Ser. No. 08/109,122, filed Aug. 13, 1993.

In FIG. 12, a groove 90 is laser scored into an untreated leather cover 88.

FIG. 13 illustrates the process applied to a cosmetic cover layer 92, shown as a textile material as might be used with a side impact air bag system, which has a scrim backing layer 94 bonded thereto.

The laser scored groove 95 penetrates completely through the backing scrim 94 and partially through the textile layer 92.

FIGS. 14 and 15 show applications to miscellaneous composites.

In FIG. 14, a cosmetic skin 96, such as a vacuum formed vinyl sheet, is applied over a metal substrate 98 (such as aluminum or steel). In this instance, the laser scoring forms a groove 100 completely penetrating the metal substrate 98 and partially penetrating the cover skin layer 96 to create the preweakening.

FIG. 15 shows a skin 96A over scrim backing 98A, penetrated with the laser scored groove 10A.

Referring to FIG. 16, a laser generator 112 can direct a laser beam 114 at the reverse side of a substrate panel 116 underlying a cover layer 118 and intervening foam layer 120 provided in a skin and foam construction.

The power of the laser beam 114 can be controllably varied so as to completely penetrate the substrate panel 116 and foam layer 120, but only partially penetrate the inside of the cover 118, as indicated, creating the preweakening by a laser scoring.

A deployment door panel 122 is thus formed at the same time, perfectly aligned with the preweakening pattern of the cover 118.

The use of a laser beam enables preweakening by other forms than a straight groove.

As shown in FIG. 17, a series of round perforations 124 or slots 126 are formed in the cover 128 by intermittent operation of the laser generator.

FIG. 18 shows a stepped, variable depth groove 130 formed in a cover 132 which varies in depth along its length. This shape may be produced by pulsating operation of the laser generator, resulting in a cyclically varying intensity laser beam.

FIG. 19 shows a localized preweakening of a cover 134 having laser scored preweakening groove 136 formed therein. A series of crossing grooves 139 are formed across the groove 136 at a selected locale. This creates a preferential intermediate point at which severing will proceed in opposite directions as indicated.

The preweakening process is readily applicable to all conventional types of trim piece construction, i.e., skin and foam with both vinyl and leather skins (vacuum formed, dry powder, molded, injection molded) vinyl clad, or hard plastic with a surface finish.

I claim:

1. A process for preweakening an automotive interior trim piece covering an air bag installation, said air bag installation including a folded air bag adapted to be inflated and deployed upon detection of a collision, said preweakening enabling formation of an air bag deployment opening extending through said trim piece by said inflating air bag pushing through said trim piece, said trim piece having a smooth, uninterrupted cover layer overlying a substrate panel associated with an air bag deployment door, comprising the steps of:

separately forming said cover layer and said substrate panel;

scoring an inside surface of said cover layer by directing a laser beam of a predetermined intensity at said inside surface of said cover layer and moving said laser beam over said inside surface in a predetermined scoring pattern while controlling said laser beam so as to produce scoring of said inside surface of said cover layer to a depth on the order of 20-80% of the thickness of said cover layer;

assembling said scored cover layer and substrate panel into a mold with an intervening space therebetween, and with said scoring pattern having a predetermined spatial relationship with said deployment door; and, filling said intervening space with a plastic foam layer to bond said cover layer and substrate panel together with said foam layer underlying said scoring pattern.

2. The process according to claim 1 wherein in said scoring steps a CO<sub>2</sub> laser beam is directed at said cover layer inside surface.

3. The process according to claim 2 further including the step of scoring said cover material with said laser beam in a transverse direction with respect to said groove to produce localized preweakening at a selected point along said groove.

4. The process according to claim 2 further including the step of back filling said groove with a diverse material.

5. The process according to claim 2 wherein said CO<sub>2</sub> laser beam is of constant intensity and said laser beam is moved along said pattern at a rate forming a constant depth groove.

6. The process according to claim 2 wherein said CO<sub>2</sub> laser beam intensity is varied and is moved at a controlled rate to create a controlled depth and width of said preweakening scoring.

7. The process according to claim 1 further including the step of sensing the thickness of said cover layer at each point

along the path of said laser beam and varying the scoring effect produced by said laser beam so as to maintain a predetermined remaining thickness of said cover layer along said scoring pattern.

8. The process according to claim 7 wherein said layer cover is formed from a dry powder slush having a rough texture on said inside surface, said scoring step causing a varying depth groove to be formed with said laser beam scoring of said rough textured inside surface.

9. The process according to claim 1 wherein said trim piece comprises a molded plastic steering wheel cover and in said scoring steps a groove is formed by said laser beam.

10. The process according to claim 1 further including the step of completely severing a portion of said cover layer by directing a laser beam at said cover and relatively moving said laser beam to sever said portion therefrom.

11. The process according to claim 1 further including the step of assembling said cover to a substrate to form said trim piece, and further including the steps of trimming said trim piece with said laser beam.

12. The process according to claim 1 wherein said CO<sub>2</sub> laser beam is varied in intensity or speed to create a scoring in said cover layer comprised of a groove of a varying depth.

13. The process according to claim 1 further including the step of mounting a laser beam generator to a robot arm and moving said robot arm to direct said laser beam from said laser beam generator at said cover layer inside surface along a path such as to score said cover layer in said pattern.

14. The process according to claim 13 further including gaging said cover layer with a gaging laser beam by moving a laser generator with a robot arm so as to impinge portions of said cover layer along a path just ahead of said scoring of said cover, generating gaging signals corresponding to any surface variance of said cover layer portions, and adjusting the scoring produced by said laser beam generator in correspondence therewith so as to maintain a substantially constant material thickness remaining above the scoring of said cover layer.

15. The process according to claim 14 wherein the speed of movement of said laser beam generator is varied in accordance with said gaging signals.

16. The process according to claim 1 wherein said laser beam is operated intermittently to create a scoring comprised of a series of holes in said cover.

17. Apparatus for prescorining an inside of an automotive interior trim piece having a substrate and an overlying cover piece, comprising:

a CO<sub>2</sub> laser beam generator of sufficient power to partially penetrate said interior trim piece;

means for supporting said trim piece and relatively moving said supported trim piece and laser beam generator to trace a scoring pattern on said interior trim piece with a laser beam to form an air bag deployment door therein; and,

control means monitoring said scoring of said trim piece during the tracing of the scoring pattern on said interior trim piece, and varying the scoring effect of said laser beam to produce only a predetermined partial penetration of said interior trim piece by said laser beam at points along the tracing of said scoring pattern.

18. The apparatus according to claim 17 wherein said control means includes sensor means for sensing the outer surface of said trim piece cover layer to vary the groove depth so as to maintain a constant thickness of remaining material.

19. A process for preweakening an automotive interior trim piece covering an air bag installation, said air bag

installation including a folded air bag adapted to be inflated and deployed upon detection of a collision, said preweakening enabling formation of an air bag deployment opening extending through said trim piece by said inflating air bag pushing through said trim piece, said trim piece having a smooth, uninterrupted covering skin layer overlying a substrate panel associated with an air bag deployment door, comprising the steps of:

separately forming said covering skin layer and said substrate panel;

scoring one side of said covering skin layer by directing a laser beam of a predetermined intensity at said one side of said covering skin layer and moving said laser beam over said covering skin layer in a predetermined scoring pattern while controlling said laser beam so as to produce scoring of said inside surface of said covering skin layer to a depth on the order of 20% or greater of the thickness of said covering skin layer; and,

thereafter mounting said covering skin layer to said substrate panel with said scoring pattern on the inside of said covering skin layer facing said substrate.

5 20. The process according to claim 19 wherein said covering skin layer comprises a skin preformed with a foam backing layer.

10 21. The process according to claim 19 wherein in said scoring steps a CO<sub>2</sub> laser beam is directed at said covering skin layer inside surface.

15 22. The process according to claim 21 further including the step of sensing the thickness of said covering skin layer at each point along the path of said laser beam and varying the scoring effect produced by said laser beam so as to maintain a predetermined remaining thickness of said covering skin layer along said scoring pattern.

\* \* \* \* \*

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 5,744,776  
DATED : April 28, 1998  
INVENTOR(S) : David J. Bauer

Page 1 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the title, delete the title and insert therefor --PROCESS AND APPARATUS FOR LASER PREWEAKENING AN AUTOMOTIVE TRIM COVER FOR AN AIR BAG DEPLOYMENT OPENING--.

Column 1, line 11, delete "Mar. 1, 1994" and insert therefor --April 22, 1993--.

Column 2, line 42, delete "briding" insert therefor --bridging--.

Column 3, line 20, delete "is".

Column 5, line 63, delete "having a physical properties"

Column 8, line 2, after "the" delete --the--.

Column 8, line 53, delete "10A" and insert therefor --100A--.

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 5,744,776  
DATED : April 28, 1998  
INVENTOR(S) : David J. Bau r

Page 2 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 1, line 10 & 11, delete "08/151,175" insert --08/051,175--.

Signed and Sealed this  
Twentieth Day of April, 1999

Attest:



Q. TODD DICKINSON

Attesting Officer

Acting Commissioner of Patents and Trademarks

## United States Patent

[11] 3,617,683

[72] Inventors Michael Patrick Beresford  
Gloucester;  
Brian Frederick Scott, Birmingham, both of  
England

[21] Appl. No. 2,505

[22] Filed Jan. 13, 1970

[45] Patented Nov. 2, 1971

[73] Assignees The University of Birmingham  
Birmingham, England;  
Spacatron Limited  
Tuffley Crescent, Gloucester, England

[32] Priority Jan. 14, 1969

[33] Great Britain

[31] 2191/69

---

[54] **METHOD AND APPARATUS FOR WORKING MATERIAL USING LASER BEAMS**  
8 Claims, 5 Drawing Figs.

[52] U.S. Cl. 219/121 L

[51] Int. Cl. B23k 9/00

[50] Field of Search 219/121 L, 121 EB, 85

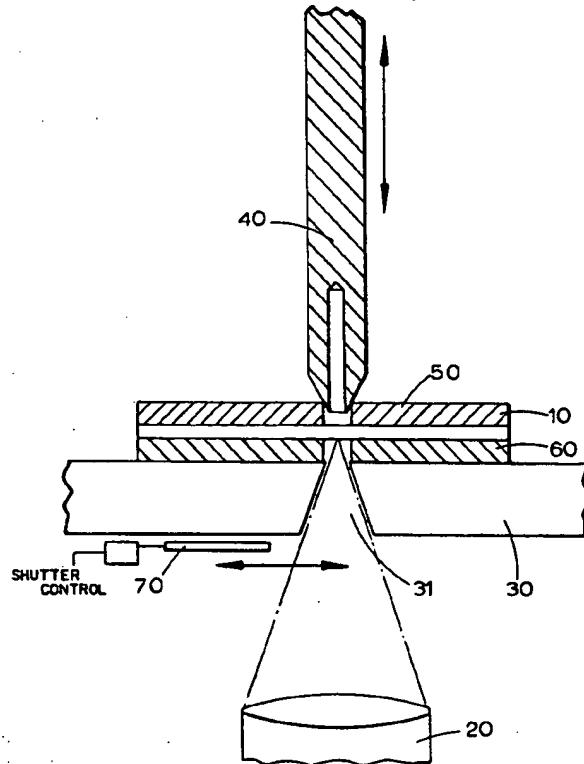
[56] References Cited

UNITED STATES PATENTS

3,334,213 8/1967 Sauve et al. .... 219/121 EB

Primary Examiner—J. V. Truhe  
Assistant Examiner—Lawrence A. Rouse  
Attorney—Shoemaker and Mattare

**ABSTRACT:** The invention relates to methods and apparatus for working materials using laser beams. The workpiece is laid on support means which include table beneath which is located a laser beam emitter and an associated optical system for focusing the laser beam. The support means, which include the worktable, has a generally vertical through hole and the workpiece is laid over this hole. The laser optical system is arranged to direct the beam from below through the hole in the support means and to focus the beam at the level of the upper end of the hole, that is, substantially on the underside of the workpiece. Means are provided above the worktable for indicating the position of the optical axis of the laser beam. Means are provided for shrouding the laser beam to prevent stray emission.



PATENTED NOV 2 1971

3,617,683

SHEET 1 OF 3

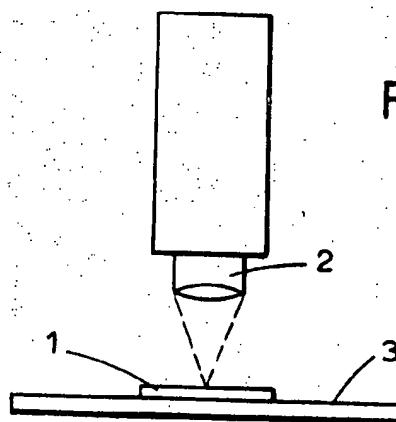


FIG. 1.  
PRIORITY ART

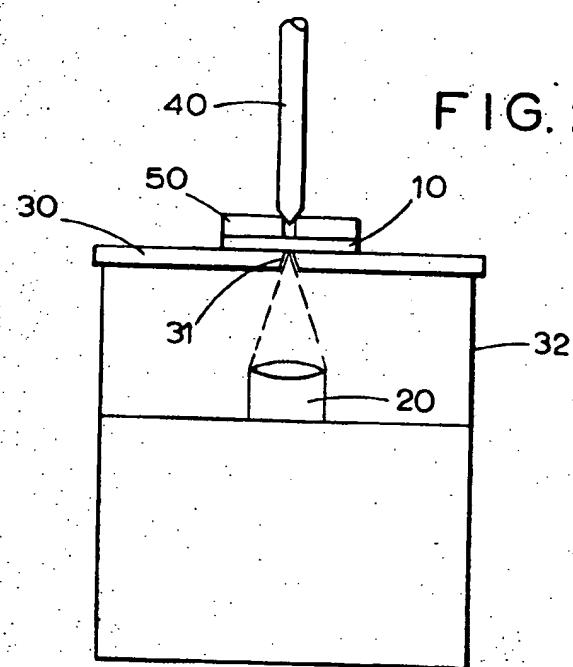


FIG. 2.

INVENTORS  
MICHAEL PATRICK BERESFORD  
BY  
BRIAN FREDERICK SCOTT  
Shanahan and Martare  
ATTORNEYS

PATENTED NOV 2 1971

3,617,683

SHEET 2 OF 3

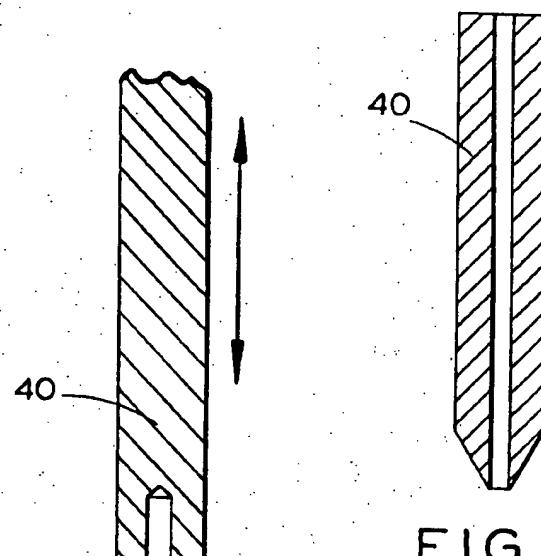


FIG. 5.

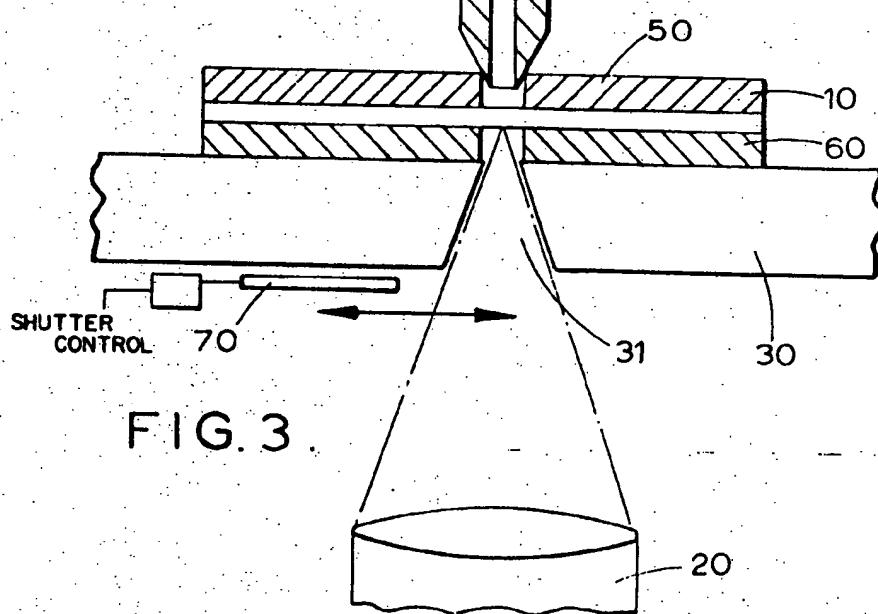


FIG. 3.

INVENTOR'S  
MICHAEL PATRICK BERESFORD  
BY  
BRIAN FREDERICK Scott  
Graemmer and Muller  
ATTORNEYS

PATENTED NOV 2 1971

3,617,683

SHEET 3 OF 3

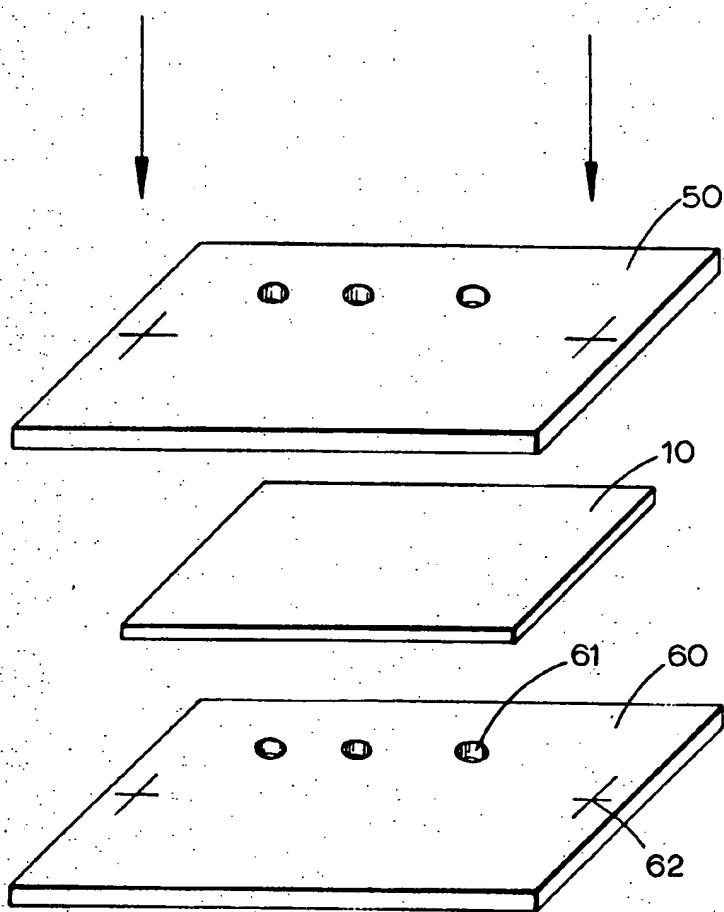


FIG. 4.

INVENTORS  
MICHAEL PATRICK BERESFORD  
BY BRIAN FREDERICK Scott  
Gloemaler and Martee  
ATTORNEYS

**METHOD AND APPARATUS FOR WORKING MATERIAL  
USING LASER BEAMS**

This invention relates to methods and apparatus for working materials using laser beams.

Machining processes employing laser (light amplification by stimulated emission of radiation) have recently come into increasing utilization and are particularly advantageous where conventional drilling presents difficulties. An example is the forming of very small holes in ceramic substrates for microelectronic components in integrated circuits. However, this is but one of many uses of laser in machine tools.

When using laser as the energy source for working materials, it is necessary to avoid possible injury to the operator or to any person who may be in the vicinity of the system. The rays of visible and at times invisible light generated by a laser as electromagnetic radiation can have extremely high power outputs, and can cause serious damage to the eyes and/or skin. When the output energy is further concentrated, as by an optical system, the power intensity (power per unit area) increases further and so increases the potential risk to humans.

Although various recommendations have been published which suggest certain safe values of energy density, and pulse values, it is considered that in any materials working system utilizing laser, the output will exceed the recommended safe values. This means that the potentially dangerous beam must be shrouded from the operator and any other person. A means by which to achieve this object will be described in this specification.

For the purposes of this specification, the beam that leaves the laser optical system and impinges upon the workpiece will be referred to as the primary beam. The reflected beam, i.e. from the workpiece to any other object will be referred to as the secondary beam.

A means will be described which gives the facility for simplifying focusing arrangements in the laser system. To achieve predictable results when materials working using a laser system, it is necessary to know the power intensity (power per unit area) of the output incident upon the workpiece. It is usually required to focus the output beam on, or very close to the surface of the workpiece. This infers that for different thicknesses of workpiece, the laser optical system must be refocused, or that the workpiece must be moved with respect to the focal plane.

FIG. 1 of the accompanying drawings shows a commonly used layout for a laser materials working system. Here the workpiece 1 is disposed between the laser optical system generally designated 2 and a table 3. The difficulties of shrouding the primary and secondary beams and positioning the workpiece accurately with respect to the beam center line are overcome, for example, by enclosing the workpiece and providing remote manipulation.

The laser beam requires to be focused at a known point relative to the point of entry to the workpiece and one disadvantage of conventional systems is the need to refocus the laser optical system after a new workpiece has replaced a previous one having a different thickness. The correct positioning of the workpiece relative to the laser beam center line has also proved difficult especially when a succession of differently shaped workpieces are involved, since the operator is not able to see the working area until the laser has been fired. Such difficulties of conventional systems can to a limited extent be overcome by the provision of expensive and complex remote viewing equipment.

Broadly stated the present invention provides a method of working materials utilizing a laser beam which comprises laying the workpiece on support means and directing the laser beam from below upwardly through a hole in the support means against the underside of the workpiece and focusing the laser beam at the level of the upper end of the hole in the support means.

This procedure provides the advantage that as the level of the upper end of the hole in the support means can be accurately determined a laser beam prefocused at this level, will be

correctly focused for workpieces of various thickness laid over the hole in the support means. An equally important practical advantage is that the support means may be employed to shroud the laser beam to prevent stray emission.

Moreover, in conjunction with other means described below, there is obtained apparatus which, during its operation, presents little or no danger to persons supervising the process.

One apparatus according to the present invention for working materials using laser beams comprises support means in the form of a worktable having an aperture, there being beneath said worktable and shrouded at least in part thereby, a laser beam emitter and an optical system adapted to direct the primary beam upwardly through said aperture and to focus said beam substantially at the level of the top of the aperture in the worktable so as to be correctly focused on the underside of a workpiece laid on the table over said aperture, irrespective of the thickness of the workpiece.

According to a further preferred aspect of the invention for centering the workpiece there is provided above the table a probe arranged to be movable along the axis of the laser beam and which probe can be lowered on to the workpiece to indicate on the upper side thereof the position of the axis.

Preferably the probe is arranged so that if it is further lowered in the absence of a workpiece, it closes said aperture, and acts as a further safeguard in the event of inadvertent emission of the laser beam.

A shutter may be provided which normally closes the aperture in the worktable, but which is mechanically or electrically coupled with the probe, whereby the shutter is automatically removed when the probe is lowered into contact with the workpiece.

Coupled with the probe operation there may be provided safety switch means which are effective to prevent laser beam emission except when the probe is lowered into contact with a workpiece or to close said aperture.

In practice, a tooling template will be located above the workpiece and this will have indicator means by which it can be readily and correctly aligned with the probe.

In a further alternative arrangement, the workpiece is located between a template and a backing plate having a plurality of holes in register with those of the template. As the backing plate is laid on the table the laser optical system will be adjusted to focus the beam at the level of the upper surface of the backing plate.

Various embodiments of the invention are illustrated diagrammatically in FIGS. 2 to 5 of the accompanying drawings in which,

FIG. 2 shows the relative dispositions of a laser emitter, a laser optical system, a worktable and a workpiece in one method of operation according to the invention;

FIG. 3 illustrates a modified method of operation in which the workpiece is located between a template and a backing plate shown also in perspective view in FIG. 4;

FIG. 5 illustrates a locating probe which may be employed with the apparatus of FIGS. 2 or 3.

Referring first to FIG. 2, 10 represents a workpiece, for example a ceramic substrate for microelectronic components, which require to have a through hole formed in it using a laser beam.

According to the invention, the laser emitter and its optical system generally designated 20 are located beneath a worktable 30 and the optical system 20 is arranged to direct the beam through a hole 31 formed in the worktable 30.

The worktable 30 partially shrouds the beam, and shrouding is continued by shielding walls 32 laterally enclosing the emitter and the optical system 20.

When, as shown in FIG. 2, the workpiece 10 is laid directly on the table 30, the optical system can be adjusted to prefocus the laser beam at the level of the upper end of the hole 31, that is at the level of the upper surface of the table 30. The beam will then be correctly focused for workpieces of different thicknesses laid on the table 30 over the hole 31.

To indicate the axis of the laser beam and hence to assist in correct location of the workpiece 10, a probe 40 will be provided movable towards or away from the hole 31 along the axis of the beam. In conjunction with the probe a template 50 may be provided carrying the workpiece at its underside. The workpiece 10 may then be located by registering the probe 40 with a hole 51 in the template 50.

Alternatively and as shown in FIGS. 3 and 4, the workpiece 10 may be sandwiched between a template 50 and a baseplate 60, the latter having one or more holes 61 for registering with the hole 31 in the worktable 30. As shown the baseplate 60 has three such holes and by providing three corresponding holes in the template 50, the probe may be employed to register the workpiece so that three holes may be accurately formed therein by appropriate repositioning of the sandwich over the hole 31. The template 50 and baseplate 60 will be formed with appropriate keying means at locations designated 62.

The probe may as shown in FIGS. 2 and 3, be a simple rod with a pointed or frustoconical lower end for registering with the template. Alternatively as shown in FIG. 5 the probe 40 may have a hollow bore so as to permit a drill or reamer to be passed down its bore in order to enlarge a hole formed by the laser beam.

The probe 40 constitutes a useful safety device in that when it bears on the hole in the template 50 it prevents stray emission of the laser beam, even if the beam has penetrated through the workpiece. Accordingly, means are preferably provided for preventing the laser emitter from operating except when the probe is bearing either on the hole 51 or on the hole 31. These means will comprise simple mechanical or electrical interlocks of a form well known in the art of machine tools.

Such simple mechanical or electrical interlocks may also be employed to control a shutter 70 shown in FIG. 3 and arranged to mask the hole 31 in the worktable 30. The shutter 70 will be arranged to unmask the hole 31 only when the probe encounters resistance on being moved downwardly.

The following objectives can, therefore, be achieved in accordance with this invention:

1. By reference to FIGS. 2 and 3 it can be seen that the primary and secondary beams are completely contained irrespective of material thickness. The probe and the shutter can be provided with simple mechanical and/or electrical interlocks to isolate the laser if the system is not sealed by workpiece and correctly positioned probe.

2. The working plate remains constant irrespective of material thickness and so avoids the need for repositioning the focal plane when working different material thicknesses.

3. The need for remote viewing, illumination and focusing is avoided.

4. The probe provides a means of accurately positioning the workpiece relative to the laser beam centerline. Simple tooling techniques can be used to achieve specified patterns of material working. One example is shown in FIG. 3.

5. Operations subsequent to the laser beam operation may be achieved by allowing, i.e., a drill broach or reamer to pass through the probe and into the workpiece without repositioning the workpiece.

We claim:

1. A method of working materials utilizing a laser beam

which comprises laying the workpiece on support means and directing the laser from below upwardly through a hole in the support means against the underside of the workpiece and focusing the laser beam at the level of the upper end of the

5 hole in the support means, and including the step of assembling the workpiece beneath a template and utilizing indicator means located above the support means to locate the template in desired position relative to the optical axis of the laser beam, said template having a through hole, and said indicator means including a probe located above the support means and movable along the optical axis of the laser beam into a position when it is in contact with the template and at least partially obturates the hole in the template, and there being means for preventing emission of said laser beam except when said probe is in predetermined position.

10 2. A method according to claim 1, wherein, emission of said laser beam is permitted only when said probe is in position at least partially obturating said hole in said template.

3. Apparatus for working materials utilizing a laser beam 20 comprising support means having a generally vertical hole through said support means terminating at the upper surface thereof, a laser beam emitter and optical system located below said support means and arranged to project a laser beam upwardly through said hole and to focus the said beam at the

25 level of the termination of the hole at the upper surface of the support means, a probe located above the support means and movable along the optical axis of the laser beam, the probe having at its lower end means for showing the location of said optical axis, and means for preventing emission of said laser beam except when said probe is in predetermined position relative to said hole.

30 4. Apparatus according to claim 3, wherein said probe is a rod having a hollow axial through bore.

5. Apparatus according to claim 4 including a shutter means 35 arranged to mask the underside of the hole in the support means.

6. Apparatus according to claim 4 including shielding walls surrounding said laser emitter and optical system and with said support means constituting a shroud preventing stray emission 40 from said laser beam.

7. Apparatus for working material utilizing a laser beam comprising a worktable with a generally horizontal upper surface, a substantially vertical hole through said worktable terminating at the upper surface thereof, a laser beam emitter 45 and an optical system located below the worktable and adapted to direct a primary laser beam upwardly through said hole, a backing plate laid on said table, a template secured to said backing plate and spaced vertically therefrom, the space between the backing plate and the template being adapted to

50 be occupied by a workpiece, at least one through hole in said backing plate registering with a through hole in the template and with the hole in the worktable, a probe located above said template and movable along the optical axis of the laser beam into a position when it is in contact with the template and at least partially obturates the through hole therein, and means for preventing emission of said laser beam except when said probe is in predetermined position.

8. Apparatus according to claim 7 wherein emission of said laser beam is permitted only when said probe is in position at least partially obturating said hole in said template.

\* \* \* \*